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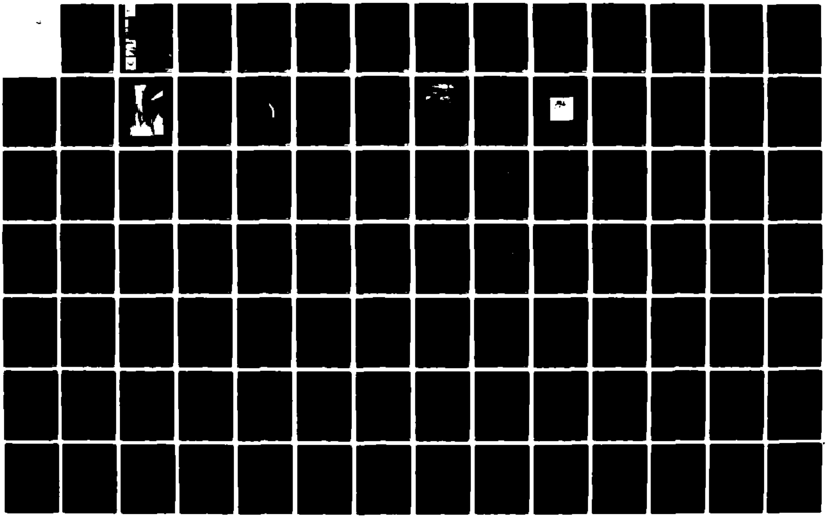

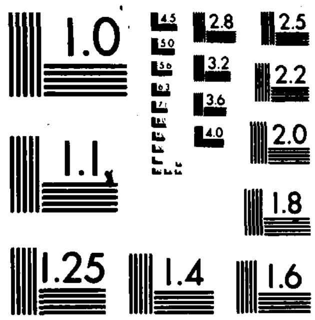

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LOS ANGELES AND LONG BEACH HARBORS MODEL STUDY

RESONANT RESPONSE OF THE HARBORS FOR PHASE I OF THE LOS ANGELES DEEP-DRAFT DRY BULK EXPORT TERMINAL

by

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Final Report

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A study of harbor resonance due to long-period wave excitation was conducted in the Los Angeles and Long Beach Harbors hydraulic model for Phase I of the proposed Los Angeles deep-draft dry bulk export terminal, and results were compared with resonant response for existing conditions. Proposed modifications for the deep-draft dry bulk export terminal included (a) dredging a navigation channel and maneuvering area and (b) creating a new landfill of
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20. ABSTRACT (Continued).

approximately 340 acres in the Port of Los Angeles.

Wave periods ranging from 67.5 to 280 sec with incident direction of approach from the south were used in the study. Previous refraction studies have shown that due to offshore topography, Los Angeles and Long Beach Harbors are well protected from all incident long-period wave directions, except from the south. Results of the study show wave-height amplification, periods of maximum response, and modes of oscillation for various berthing areas. It was concluded from test results that

a. The deep-draft dry bulk export terminal, in general, would result in little change in wave-height amplification throughout the existing harbors complex.

b. Wave-height amplification in West Channel of the Port of Los Angeles would decrease with the dry bulk export terminal installed.

c. Resonant peaks would develop in East Channel of the Port of Los Angeles with the deep-draft export terminal installed that do not occur for existing conditions.

d. Wave-height amplification in Southeast Basin of the Port of Long Beach would be no worse with the Los Angeles dry bulk export terminal installed than for existing conditions.

e. Although long-period wave-height amplification would be relatively low (maximum of 4.2 at gage 23) near the piers of the proposed Los Angeles deep-draft dry bulk export terminal, the berthing area would be exposed to incident short-period wave attack through the breakwater entrance.

f. Wave-height amplification in East Basin and Back Channel of the Port of Long Beach would not be significantly changed by the installation of the Los Angeles deep-draft dry bulk terminal.

PREFACE

This report presents the results of a harbor resonance study conducted in a physical model for Phase I of the proposed Los Angeles, California, Deep-Draft Dry Bulk Export Terminal. A request for the model investigation was initiated by the District Engineer, U. S. Army Engineer District, Los Angeles (SPL). The study was authorized by the Office, Chief of Engineers, U. S. Army, and funds for the U. S. Army Engineer Waterways Experiment Station (WES) to conduct the study were authorized on 7 April 1983.

The model study was conducted during the period May 1983-August 1983 by personnel of the Wave Dynamics Division (WDD) under the direction of Messrs. C. E. Chatham, Jr., Chief, WDD, and D. G. Outlaw, Research Hydraulic Engineer. The model investigation was initiated in the Hydraulics Laboratory (HL) under the general direction of Messrs. H. B. Simmons and F. A. Herrmann, Jr., Chief and Assistant Chief, respectively, HL. On 1 July 1983, WDD was transferred to the Coastal Engineering Research Center (CERC) under the general direction of Dr. R. W. Whalin and Dr. L. E. Link, Jr., Chief and Assistant Chief, respectively. Model tests were conducted by Messrs. M. G. Mize and L. A. Barnes, Civil Engineering Technicians, Ms. M. L. Hampton, Computer Technician, and Mr. L. L. Friar, Electronics Technician, under the supervision of Mr. R. R. Bottin, Jr., Project Manager. Mr. K. A. Turner, Computer Specialist, and Ms. Hampton developed the plots used for comparisons of model data. This report was prepared by Messrs. Bottin and Outlaw.

During the course of the investigation, liaison between SPL and WES was maintained by means of conferences, telephone communications, and monthly progress reports.

The following personnel visited WES to observe model operation and/or participate in conferences during the course of the model study.

Mr. Dan Muslin	Los Angeles District (SPL)
Ms. Barbara Hill	Ocean Studies Corporation
Mr. Joe Thomas	Port of Los Angeles
Mr. Mike Burke	Port of Long Beach

Commander and Director of WES during the conduct of this investigation and preparation and publication of this report was COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
acres	0.4046873	hectares
feet	0.3048	metres
inches	25.4	millimetres
miles (U. S. statute)	1.609347	kilometres
square feet	0.09290304	square metres
square miles (U. S. statute)	2.589998	square kilometres

LOS ANGELES AND LONG BEACH HARBORS MODEL STUDY

RESONANT RESPONSE OF THE HARBORS FOR PHASE I OF THE LOS ANGELES DEEP-DRAFT DRY BULK EXPORT TERMINAL

PART I: INTRODUCTION

Background and Model Study Objectives

1. The ports of Los Angeles and Long Beach are in San Pedro Bay along the southern coast of California (Figure 1). The ports have, historically, experienced long-period surge activity which occasionally results in mooring difficulties for ships berthed in various locations within the harbors complex. Development of the harbors and past resonance characteristics of the harbors have both been reviewed in detail as a portion of a study (Wilson et al. 1968) completed by Science Engineering Associates for the U. S. Army Engineer District, Los Angeles.

2. The model investigation reported herein was conducted as only a part of the overall Los Angeles and Long Beach Harbors Study, which included the following four major objectives:

- a. Determine the incidence and severity of troublesome oscillations in the present harbor complex.
- b. Investigate the tidal circulation characteristics of the present and proposed harbors.
- c. Determine the optimum plan for future expansions to provide safe and economical berthing areas.
- d. Analyze the effect that proposed expansions will have on the existing harbors.

3. Prototype wave, tide, and ship motion data were acquired in the harbors over a 1-year period and are detailed in Pickett, et al. (1975) and Crosby and Durham (1975). Analysis of prototype wave and ship motion data are described in Durham et al. (1976).

4. In the existing harbors, troublesome ship mooring conditions are occasionally experienced in East Channel of the Port of Los Angeles and in Southeast Basin of the Port of Long Beach, along the edge of Pier J, and near the west end of Basin 6. The location of the city boundary and the various

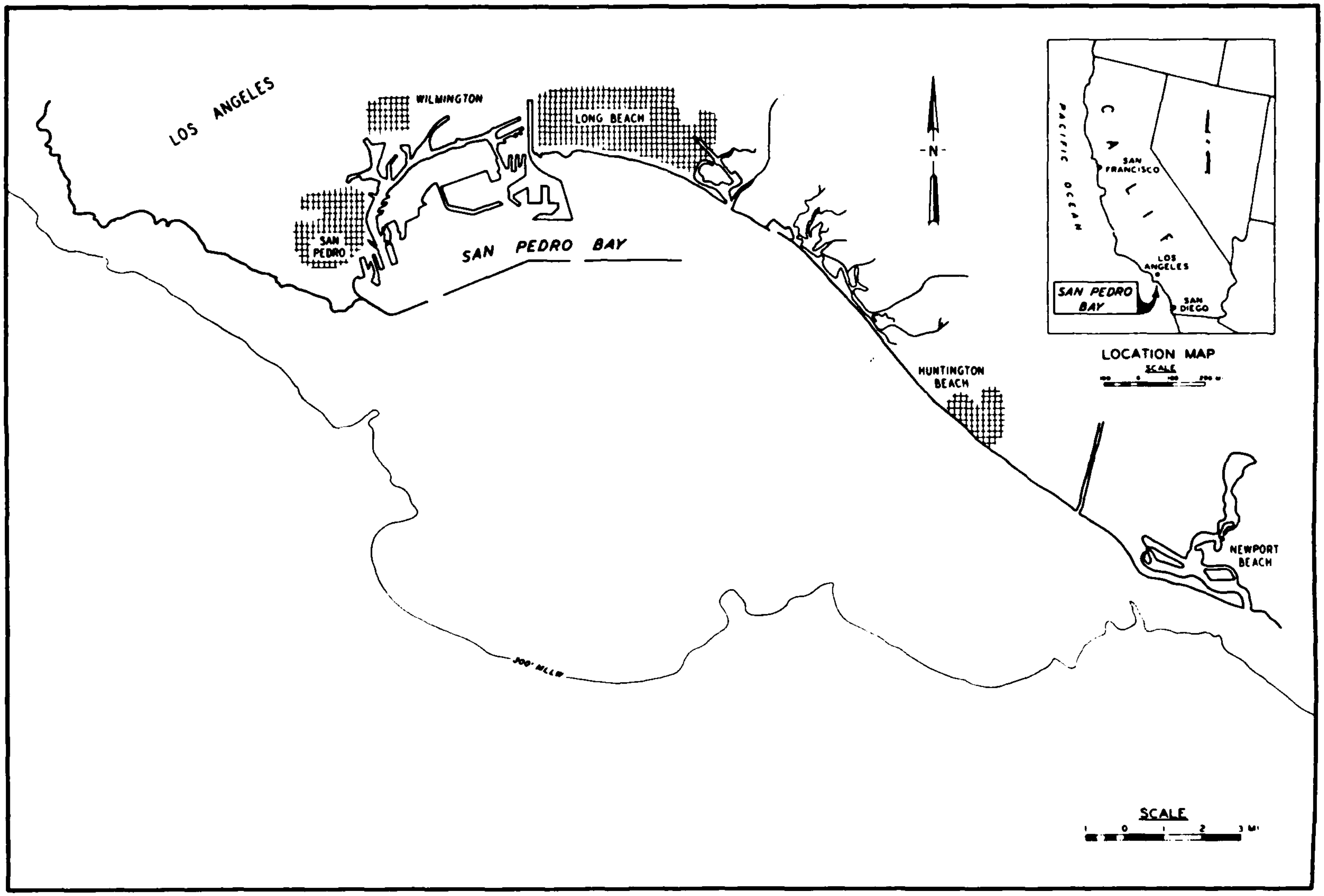

Figure 1. Vicinity map

channels and basins comprising the harbors when the study was initiated are shown in Figure 2.

5. The hydraulic model investigation of harbor resonance for Phase I of the Los Angeles Deep-Draft Dry Bulk Export Terminal was conducted to satisfy portions of objectives c and d. A careful examination of the effect of proposed improvements is necessary to ensure that the optimal cost-effective plan is developed to minimize the potential for undesirable effects which could prove either irreversible or extremely costly to correct.

Proposed Improvements

6. Phase I of the proposed Los Angeles Deep-Draft Dry Bulk Export Terminal improvement plan is shown in Figure 3. Improvements consist of the following:

a. A 600-ft*-wide, 65-ft-deep channel extending from a point seaward of Angel's Gate northerly to a maneuvering and docking area.

b. A 65-ft-deep maneuvering and docking area.

c. Two wharves adjacent to Terminal Island.

d. A landfill comprising approximately 340 acres.

7. Modifications installed in the harbors complex since model testing of the base plan (existing conditions) (Outlaw 1979) included:

a. Deepening of the Los Angeles Main Channel to 45 ft.

b. Construction of a marina in West Channel of the Los Angeles Harbor.

c. Extension of the 60-ft-deep Long Beach Channel into the Middle Harbor and Back Channel.

d. A modification to the southeast portion of Terminal Island adjacent to Back Channel.

e. A modification to Inner Harbor in the Port of Long Beach.

f. Construction of a marina east of the Los Angeles River in the vicinity of the oil island.

These modifications are not part of the proposed deep-draft dry bulk terminal plan but have been constructed in the prototype since the start of model investigation and were installed in the model prior to testing of the deep-draft dry bulk terminal.

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

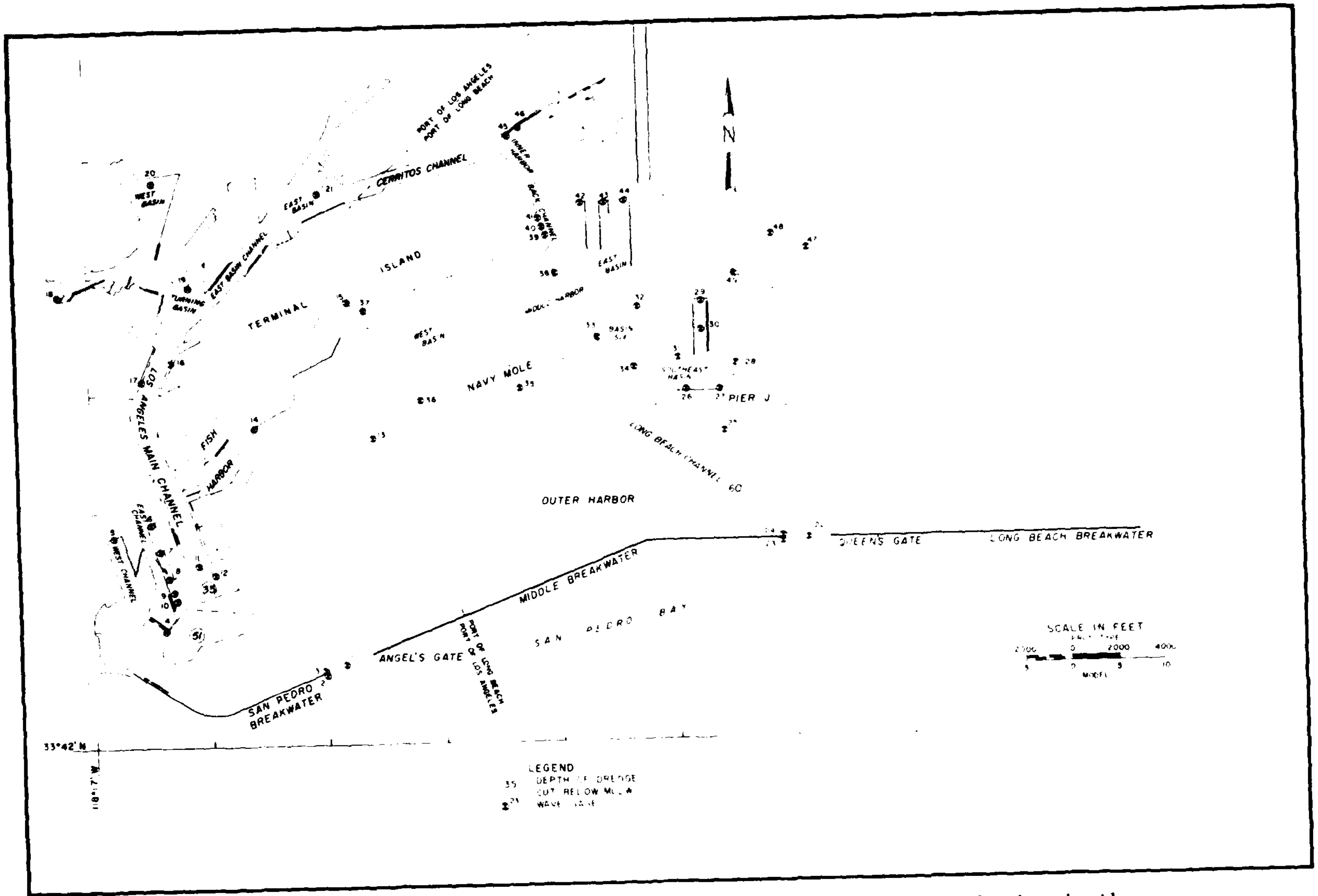

Figure 2. Location of city boundary and existing channels and basins in the Los Angeles and Long Beach Harbors

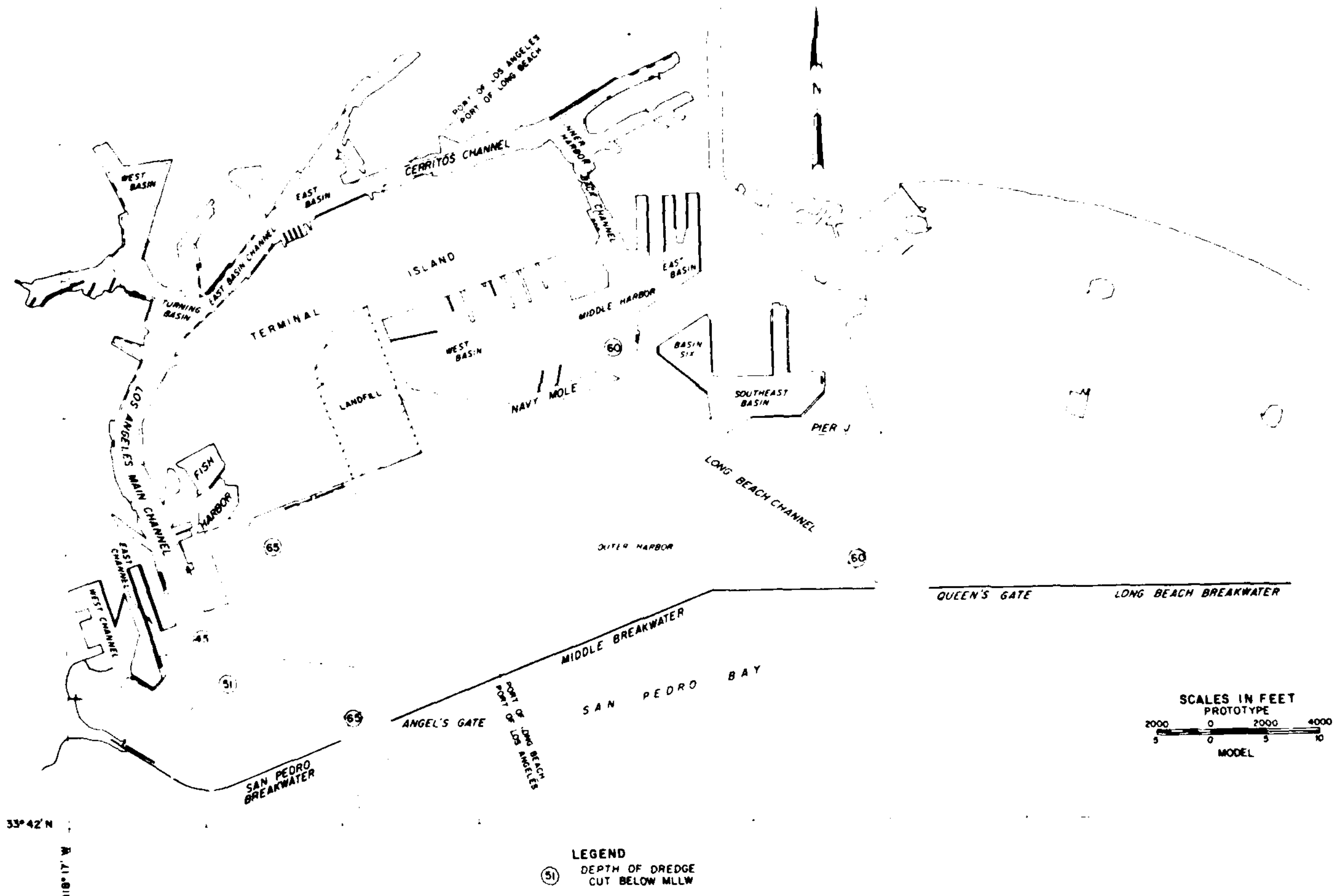

Figure 3. Elements of the proposed Los Angeles Deep-Draft Dry Bulk Export Terminal plan

PART II: MODEL DESIGN

Model Description

8. The Los Angeles and Long Beach Harbors model (Figure 4) was molded in concrete grout and reproduced San Pedro Bay and a portion of the Pacific Ocean surrounding the harbor. The model shoreline extended from approximately 2 miles northwest of Point Fermin to Huntington Beach. Underwater contours were reproduced to an offshore depth of -300 ft, and additional sufficient offshore area was included to provide space for the wave generators and tide generator utilized in model operation. The total area reproduced in the model was approximately 44,000 sq ft, representing about 253 sq miles in the prototype. A general view of the model showing the harbors area is presented in Figure 5.

9. The model was constructed to linear scale ratios, model to prototype, of 1:100 vertically and 1:400 horizontally. Depth data for model contours were obtained from the U. S. Coast and Geodetic Survey (now National Ocean Service) Charts 5101 and 5147 and from detailed harbor soundings provided by the ports. Vertical control for model construction was based on mean lower low water.* Horizontal control was referenced to a local prototype coordinate system. Major piers and wharves were reproduced in the model with 1/16- and 1/32-in.-diameter brass rods used to simulate pier pilings. The bays east of the harbors (Alamitos Bay and Anaheim Bay) were correctly reproduced in plan, but depths were averaged in the model in order to expedite construction and, at the same time, to permit proper reproduction of approximate tidal prisms. If future studies in these areas are required, the actual bathymetry can be installed in the model with relative ease.

Design Considerations

10. Comprehensive investigations of the following items were conducted during model design to aid in selection of proper model scales and limits in order to ensure accurate reproduction of long-period wave excitation:

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* All elevations (el) cited herein are in feet referred to mean lower low water (mllw) unless otherwise defined.

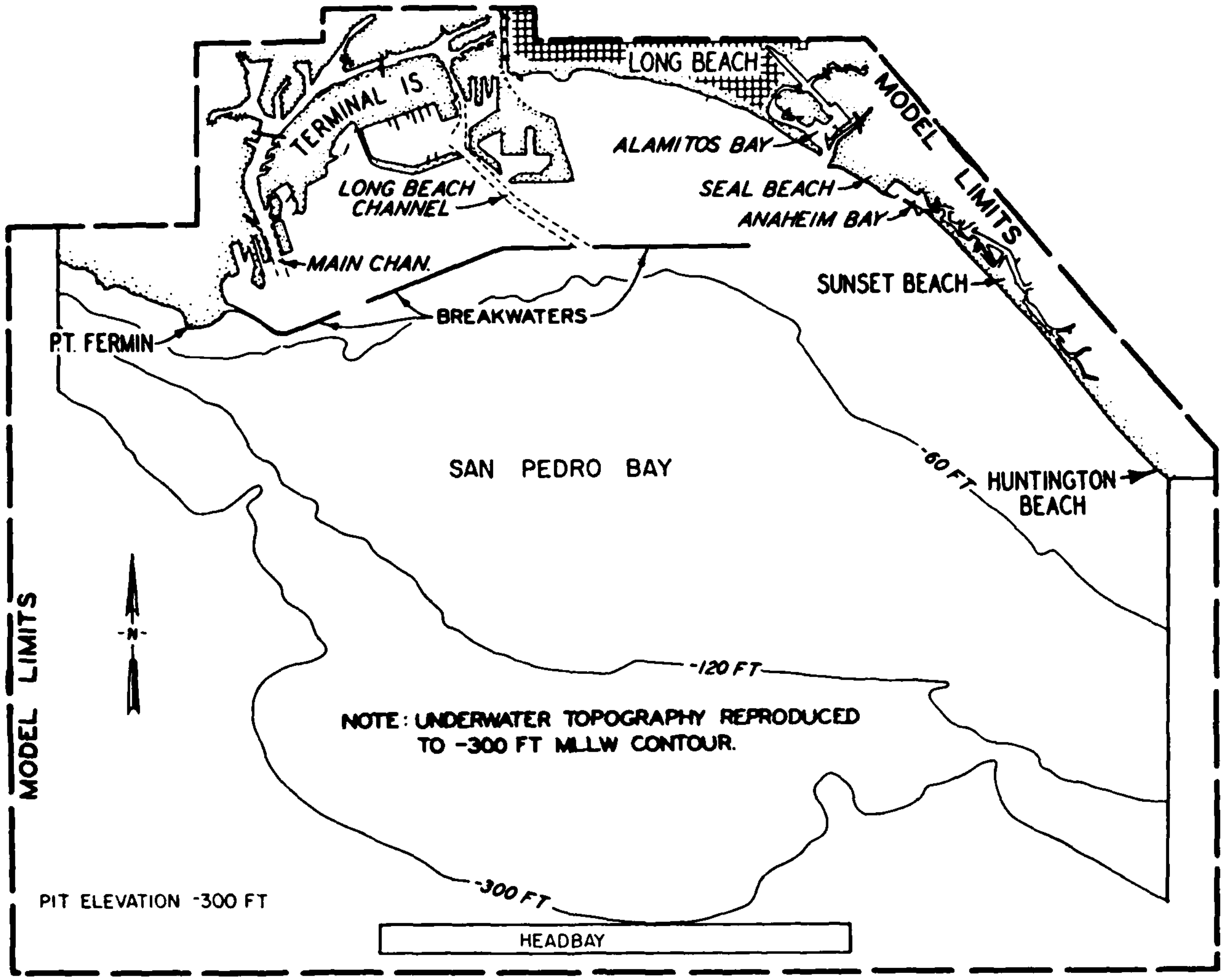


Figure 4. Los Angeles and Long Beach Harbors model

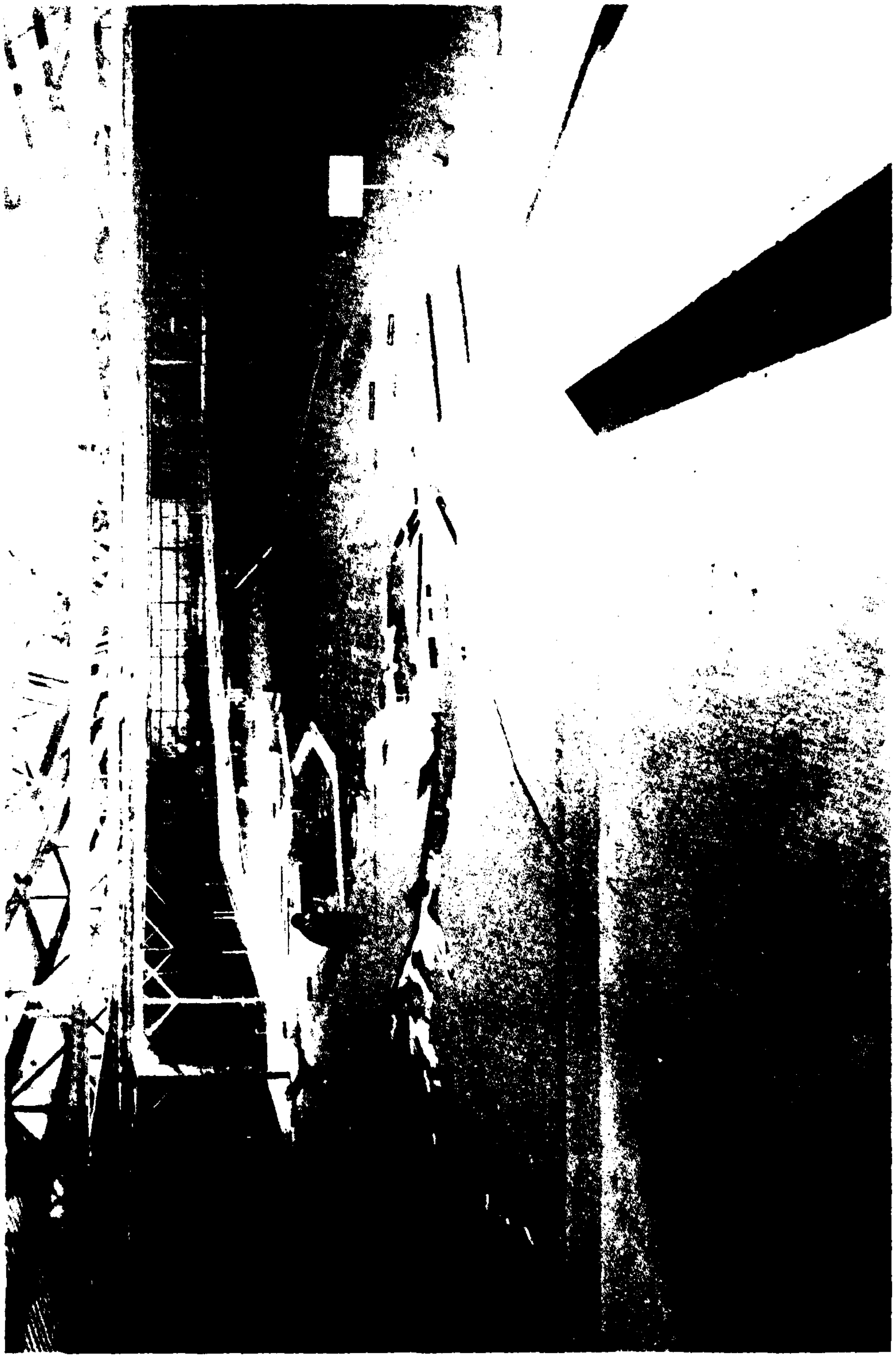


Figure 5. General view of the Los Angeles-Long Beach Harbors model

a. Wave refraction analysis for wave periods ranging from 15 sec to 6 min.

b. Energy transmission through the breakwaters.

c. Diffraction through the harbor entrances.

d. Reflection from the offshore topography and from harbor boundaries.

e. Model wave filters and absorbers.

f. Model wave-height attenuation.

Details of these investigations are reported in Outlaw et al. (1977).

11. The following conclusions drawn from the model design analysis provide a brief summary of the criteria concerning model limits and scale selection:

a. The harbor is relatively well protected from long-period wave attack except from the south-southeast through the south-southwest.

b. A convergent zone is located seaward of the harbor breakwater for the 15- to 360-sec wave period range.

c. A model distortion ratio of 1:4 and a vertical scale ratio of 1:100 were selected to minimize model area and to provide a vertical scale ratio where accurate model measurements could be assured.

d. Near a wave period of 60 sec and below, the calculated refraction patterns for the distorted scale model changed significantly from the calculated prototype refraction patterns, and adjustment of the initial wave front in the model was necessary.

e. Wave-height variation along the prototype wave front is significant and should be reproduced in the wave tests.

The development of the convergent zone is demonstrated in the wave refraction diagram for the 60-sec wave period from the south as shown in Figure 6.

12. The time scale for wave period is based on the following equation:

$$T_m = T_p \left(\frac{\ell_{hm}}{\ell_{hp}}\right)^{1/2} \left(\frac{\tanh \frac{2\pi}{\Omega} \frac{h_m}{L_m}}{\tanh 2\pi \frac{h_m}{L_m}}\right)^{1/2} \qquad (1)$$

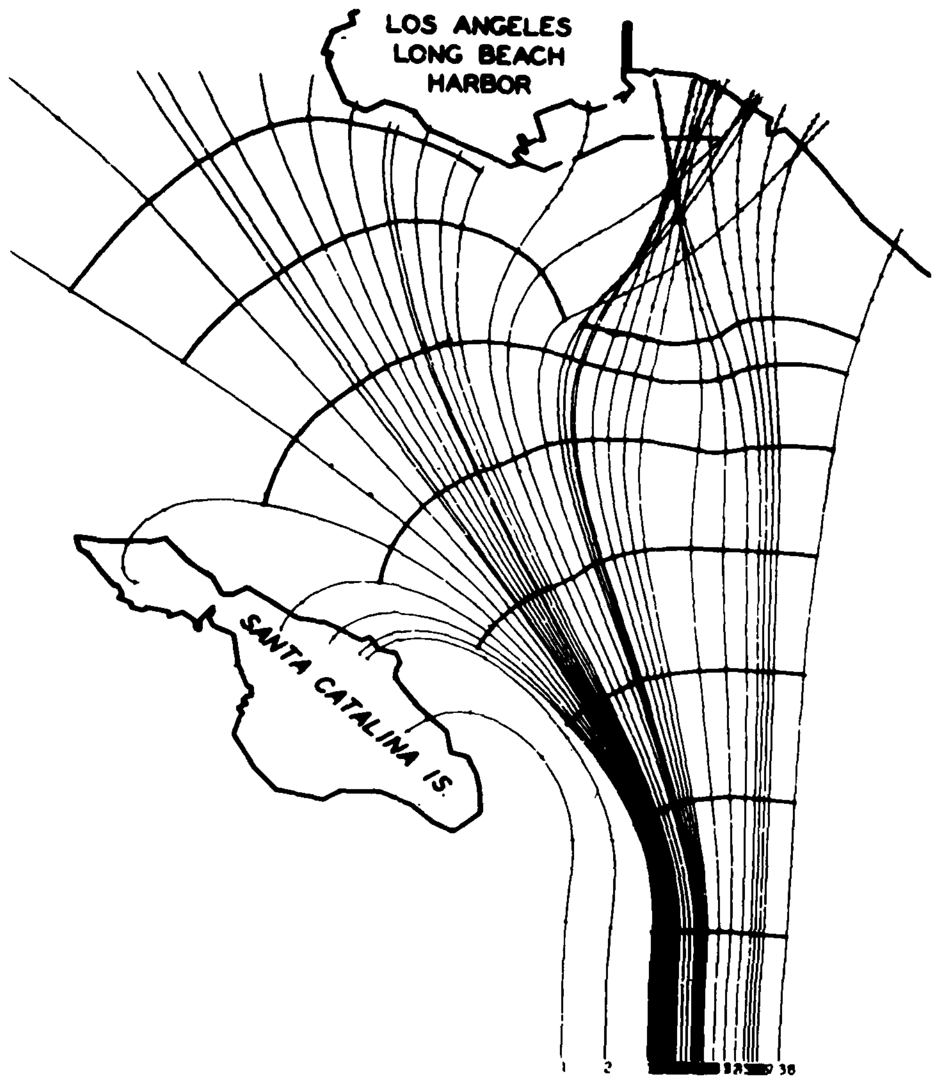


Figure 6. Refraction diagram for a 60-sec wave from the south

where

T_m* = model wave period
T_p = prototype wave period
ℓ_{hm} = horizontal length scale in the model
ℓ_{hp} = horizontal length scale in the prototype
Ω = distortion

---

* For convenience, symbols and unusual abbreviations are listed and defined in the Notation (Appendix A).

h_m = model depth of the inner harbor

L_m = model wavelength

Equation 1 is based on similitude of wavelength between model and prototype which is the proper requirement for resonance studies. In the limit as L_m, $L_p \rightarrow \infty$, Equation 1 approaches

$$T_m \cong T_p \left(\frac{\ell_{hm}}{\Omega \ \ell_{hp}} \right)^{1/2} \tag{2}$$

For an average existing harbor depth of 39 ft, the approximate model wave period calculated from Equation 2 is within 1 percent of the period calculated from Equation 1 for prototype periods $\geq$ 85 sec. At shorter periods, the dependence of the time scale on depth increases and the accuracy of the approximation represented by Equation 2 decreases.

Model Appurtenances

Wave generator

13. The model was equipped with an *electrohydraulic wave generator* capable of

- a. Generating waves with a prototype period ranging from 15 to 360 sec.
- b. Generating a wave with small variation in period and height.
- c. Defining resonant response occurring over a narrow-period band by controlling the model wave period with great precision.
- d. Generating a variable wave height along a curved wave front.

The wave generator consisted of 14 units, each with a 15-ft wave paddle, for a total length of 210 ft. The 15-ft sections were positioned to approximate a curved wave front. An example is shown in Figure 7 for prototype wave periods of 15, 20, and 30 sec. The initial prototype and adjusted model wave front locations are shown along with a comparison of wave-front locations for corresponding wave periods seaward of the harbor breakwater after formation of the convergent zone. A 15-ft unit of the wave generator with the frame, wave paddle, and hydraulic power supply is shown in Figure 8. Each unit is independently controlled from a computer-generated command signal. Performance

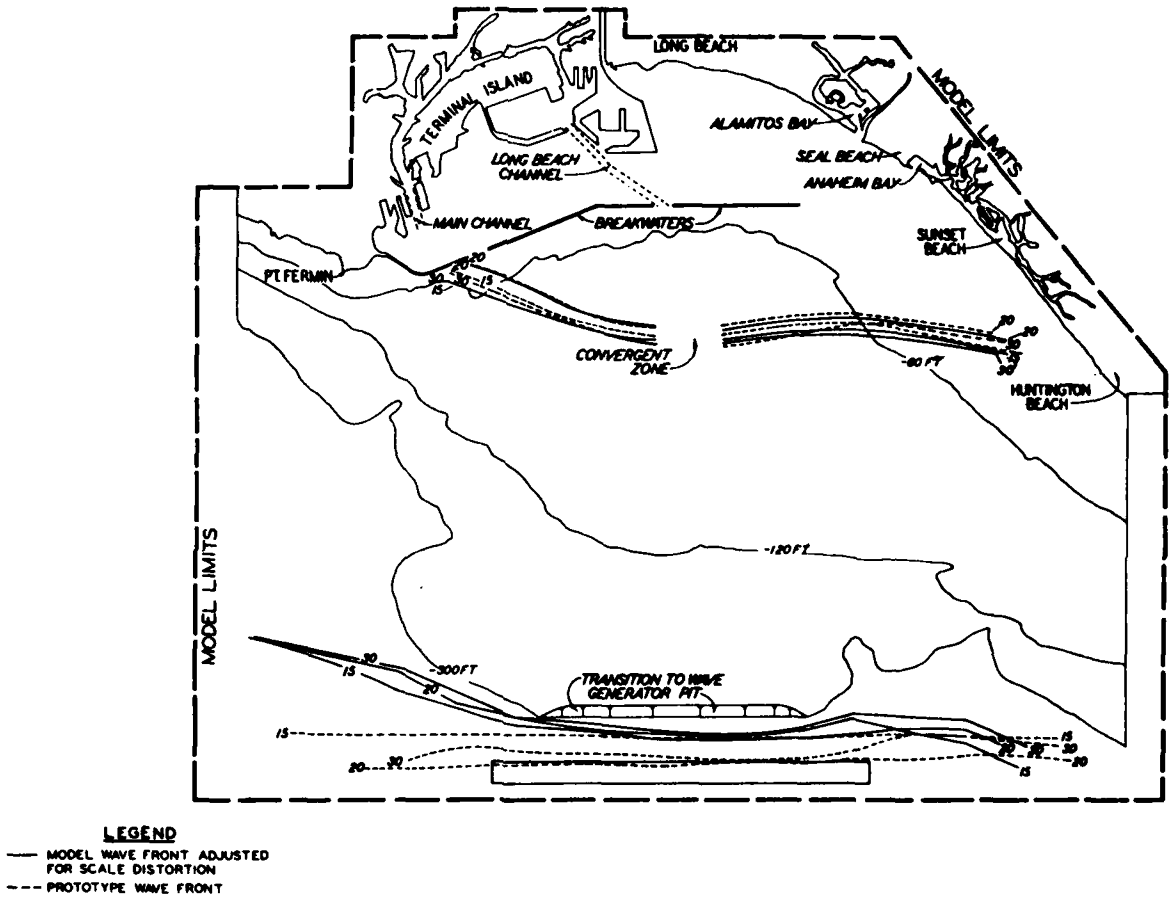


Figure 7. Comparison of model and prototype wave fronts near the -300 ft contour and near the harbor for 15-, 20-, and 30-sec waves

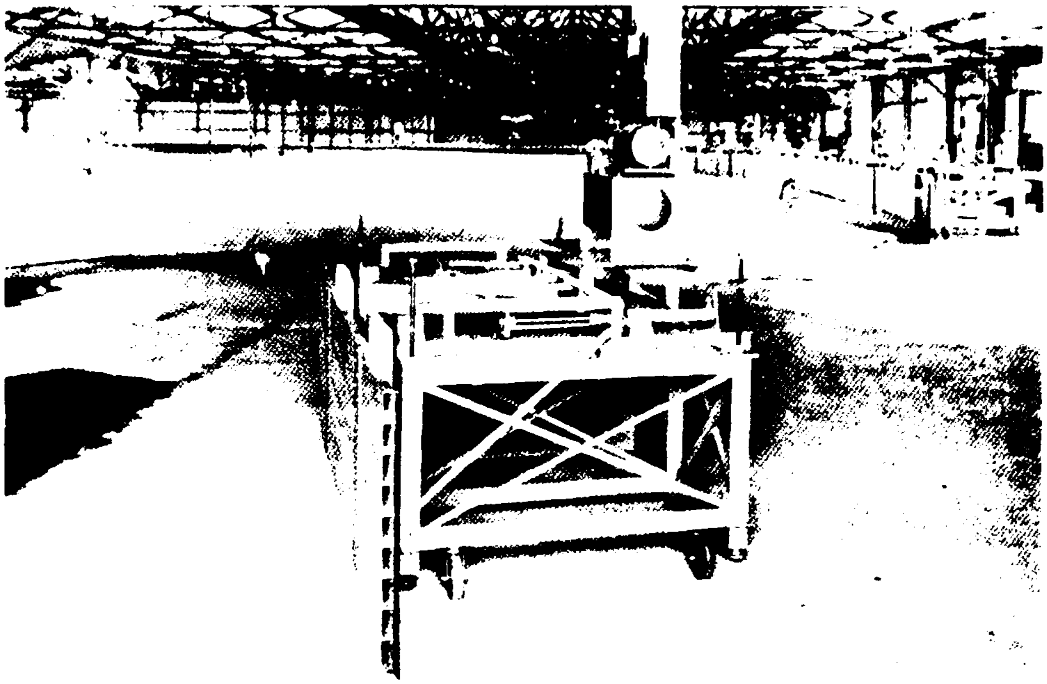


Figure 8. Electrohydraulic wave generator unit with frame, wave paddle, and hydraulic power supply

tests indicate that each unit will consistently maintain a peak-to-peak stroke error of less than 1 percent and that the maximum phase lag variation between any two of the 14 units from the command signal is 4 deg or less. Variation in the generated period is negligible for each unit. The detailed design and operation of the wave generator is discussed in Outlaw et al. (1977).

Wave data acquisition

14. Wave data acquisition in the Los Angeles and Long Beach Harbors model is controlled by an automated data acquisition and control system (ADACS; Figure 9) due to the complexity, large size, and magnitude of model wave data required. The ADACS configuration consists of four subsystems: (a) digital data recording and controls, (b) analog recorders and channel selection circuits, (c) wave and interfacing equipment, and (d) wave generators and control equipment.

15. The digital data recording and control subsystem is built around a 32K minicomputer with 16-bit words of core memory and a 1-μsec cycle time. Peripheral devices include a 1.1-million-word moving head disc and a magnetic tape controller with two 9-track tape units for data and software storage. A

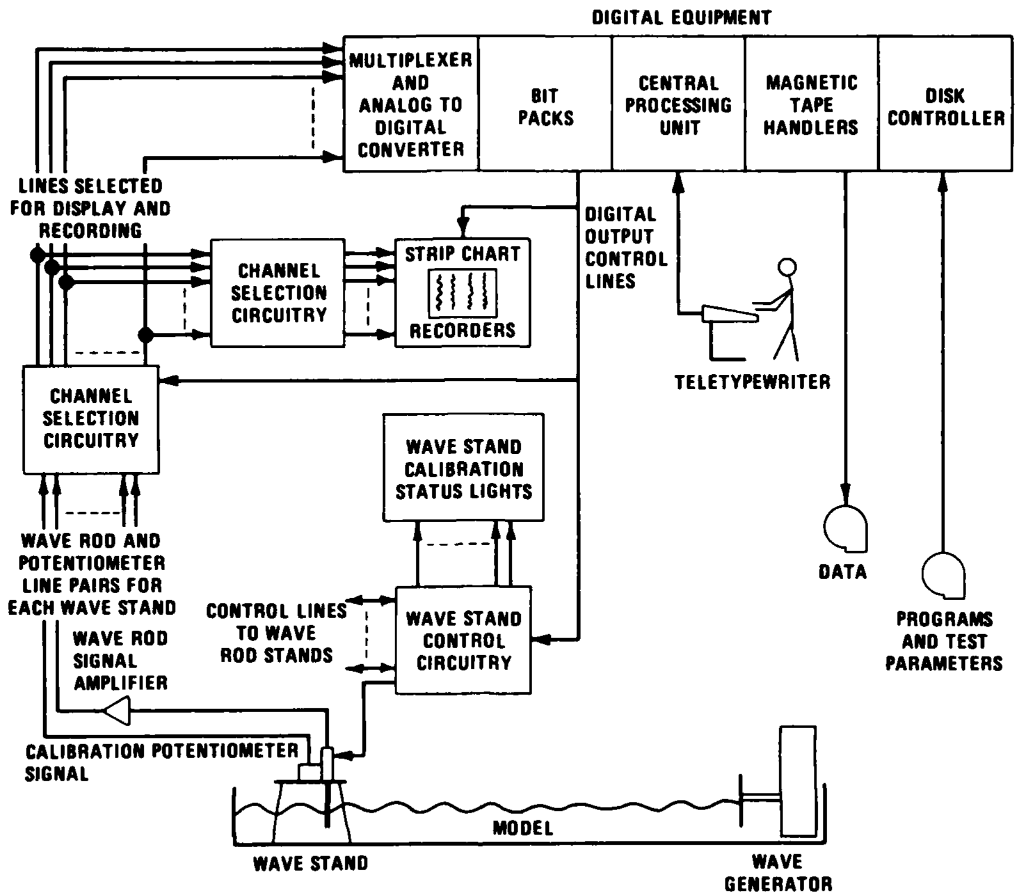


Figure 9. Automated data acquisition and control system (ADACS)

teletype unit serves as the master console, and a matrix electrostatic printer/plotter is used for output. Data acquisition is automatic without operator intervention once a wave test begins. The analog recording subsystem consists of five 12-channel oscillographs and provides a visual record of the analog wave gage signal.

16. The wave gages are parallel wire, water-surface-piercing, resistance gages (Figure 10). The gage measures the conductance of water between two vertical parallel wires. The conductance is directly proportional to the depth of submergence of the parallel wires. The gages can accurately detect changes in model water surface elevation of 0.001 ft (prototype 0.1 ft).

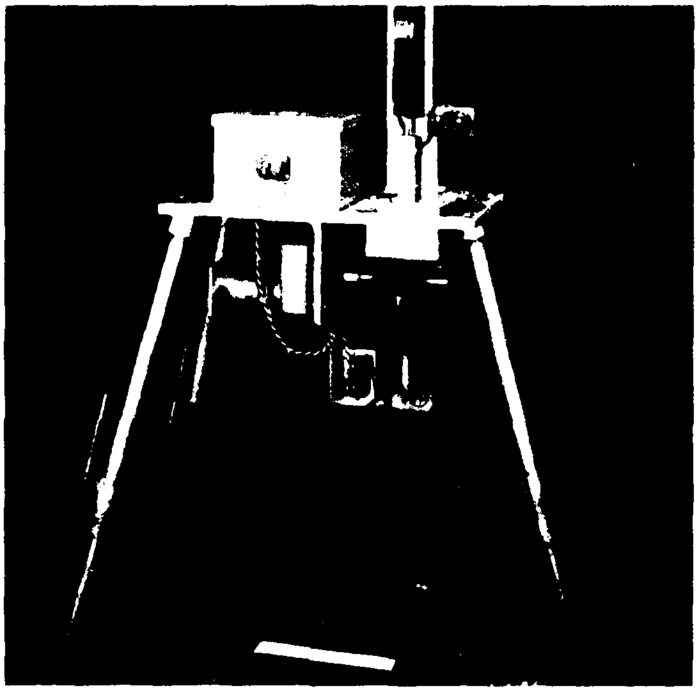


Figure 10. Parallel-wire wave sensor

PART III: DATA ANALYSIS

Test Conditions

17. Tests were conducted for long-period waves (67.5 to 280 sec) approaching the Continental Shelf seaward of the harbor from the relatively narrow long-period energy window (Wilson et al. 1968, Outlaw et al. 1977) centered around the south direction. Wave generator positions computed for various wave-period ranges (Outlaw et al. 1977) are illustrated in Figure 11.

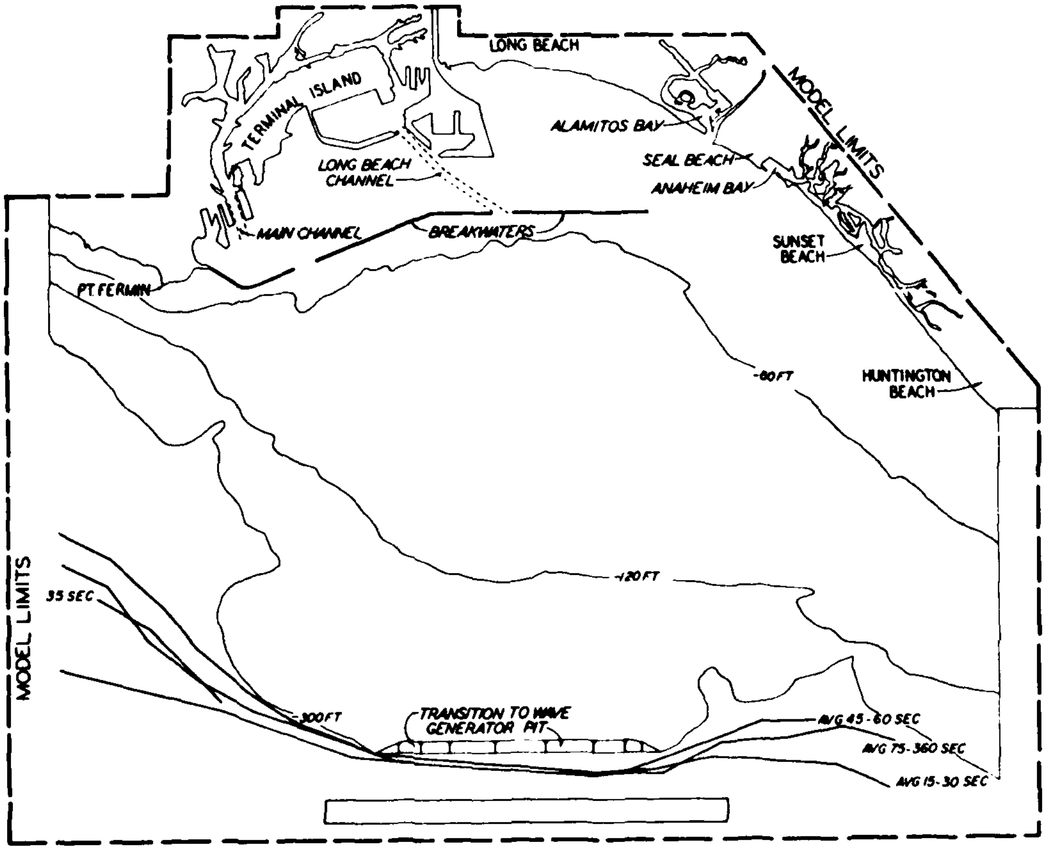


Figure 11. Mean wave generator positions

Normalized wave-height variations along the wave front were simulated in accordance with the model design refraction data. A maximum prototype wave height of 4 ft at the generated wave front was used in the 67.5- to 150-sec prototype range. Between 150 sec and 280 sec, a 3-ft maximum prototype wave height was used. The variation in wave height over these period ranges was necessary to decrease the magnitude of strong resonant oscillations and minimize finite amplitude effects on wave characteristics while maintaining sufficiently large model waves to obtain accurate model measurements throughout the area of interest. The still-water level used during model testing was +2.8 ft, and the wave period interval between tests varied from 0.5 to 2.5 sec (prototype). Smaller period increments between wave tests were used in the lower period range to ensure accurate definition of sharp resonant peaks.

Wave-Height Amplification

18. The significant wave height (H_s) at each gage location was calculated from the digital wave record (24 to 60 recorded cycles) and corrected for model scale effects due to internal and bottom friction during propagation from the wave generator to the harbor. A detailed discussion of the relatively small correction for viscous attenuation is given in Outlaw et al. (1977).

19. Wave-height amplification is traditionally defined as the ratio of the wave height at a particular location in a harbor to twice the incident wave height at the harbor mouth. This definition results from the fact that the standing wave height for a straight coast with no harbor is twice the incident wave height, due to superposition of the incident and reflected waves. In the hydraulic model, the wave heights are also affected by refraction and are variable along the outer harbor breakwater. They are significantly different at Queen's Gate and Angel's Gate and are even variable along the model wave generator. Consequently, another definition of amplification is necessary. A consistent definition can be based on the incident wave height in deep water seaward of the model wave generator location. Therefore wave-height amplification (R) for the model was calculated as the ratio of the significant wave height at each gage location to the incident wave height (H_i) which would have occurred at the initial wave-front position (approximately 38 miles seaward of the breakwater) used in the model design wave refraction analysis, or

$$R = \frac{H_s}{H_i} \tag{3}$$

The initial wave-front position for the refraction analysis is shown in Figure 6 for a 60-sec wave period. Average depth along the initial wave front is approximately 3470 ft. The model wave height (H_m) at each gage location was corrected for shoaling differences due to model distortion when calculating prototype wave heights using the following equation:

$$H_s = H_r \frac{K_s^{P,G}}{K_s^{M,G}} H_m \qquad (4)$$

where

H_r = the vertical scale ratio

$K_s^{P,G}$ = the prototype shoaling coefficient

$K_s^{M,G}$ = the model shoaling coefficient at the gage locations

Similarly, the prototype-generated wave height (H_w^P) is

$$H_w^P = K_r \frac{K_s^{P,W}}{K_s^{M,W}} H_w^M \qquad (5)$$

where

K_r = the refraction coefficient

$K_s^{P,W}$ = the prototype shoaling coefficient evaluated at the wave generator position

$K_s^{M,W}$ = the model shoaling coefficient evaluated at the wave generator position

H_w^M = the model-generated wave height

The prototype wave height at the wave generator may also be written in terms of H_i as

$$H_w^P = K_r \frac{K_s^{P,W}}{K_s^{P,A}} H_i \qquad (6)$$

where $K_s^{P,A}$ is the shoaling coefficient at the initial refracted wave-front position for the 3470-ft average depth. Substituting from Equations 2, 3, and 4, the wave-height amplification may be written in terms of model wave heights as

$$R = K_r \frac{K_s^{P,G} K_s^{M,W}}{K_s^{P,A} H_w^M K_s} H_m \tag{7}$$

The refraction coefficient is available from the model design refraction analysis, and the shoaling coefficients are a function of wavelength and water depth.

PART IV: HARBOR OSCILLATION RESULTS

Test Results

20. Wave tests were conducted for the Los Angeles Deep-Draft Dry Bulk Export Terminal plan and compared with those previously obtained for existing conditions (base plan) (Outlaw 1979). Wave gage locations in the existing harbor and the Los Angeles Deep-Draft Dry Bulk Terminal plan are shown in Plates 1 and 2, respectively. Due to the placement of gages in and near areas of proposed harbor improvement, all wave gage locations for the base plan and the Los Angeles Deep-Draft Dry Bulk Terminal plan do not correspond (31 of 49 gages are in corresponding locations). Wave-height amplification data for the Los Angeles Deep-Draft Dry Bulk Terminal plan are presented in Plates 3-51. These data are compared with amplification data for the base plan at the 31 corresponding gage locations. Base plan data (Outlaw 1979) cover a period range from 15.4 to 410 sec to provide data for comparison over an extended period range. Contour plots of the modes of oscillation for resonant periods are presented in Plates 52-73. The contour plots of wave-height amplification depict the nodes and antinodes of the resonant oscillation. Maximum currents and the maximum horizontal water displacement occur near the nodal area of the oscillation. Maximum vertical movement of the water occurs at the antinodes of the oscillation. Location of nodes, antinodes, and water particle motions for an idealized rectangular channel with a node at the channel entrance are shown in Figure 12. Where modes of oscillation were similar in amplitude and geometric configuration for the base plan and the Deep-Draft Dry Bulk Export Terminal plan, the modes of oscillation were not recontoured.

Discussion of Test Results

East Channel

21. In East Channel of the Port of Los Angeles, resonant peaks occurred at 97-, 107-, 120-, 182-, 218-, 230-, and 260-sec periods in the north (closed) end of the basin (gage 6) with the deep-draft dry bulk export terminal installed in the model. The 97- and 260-sec resonant peaks corresponded to nearby periods for the base plan. Resonant amplification exceeded 3.0 at 182, 218, and 230 sec with the export terminal installed, conditions that did

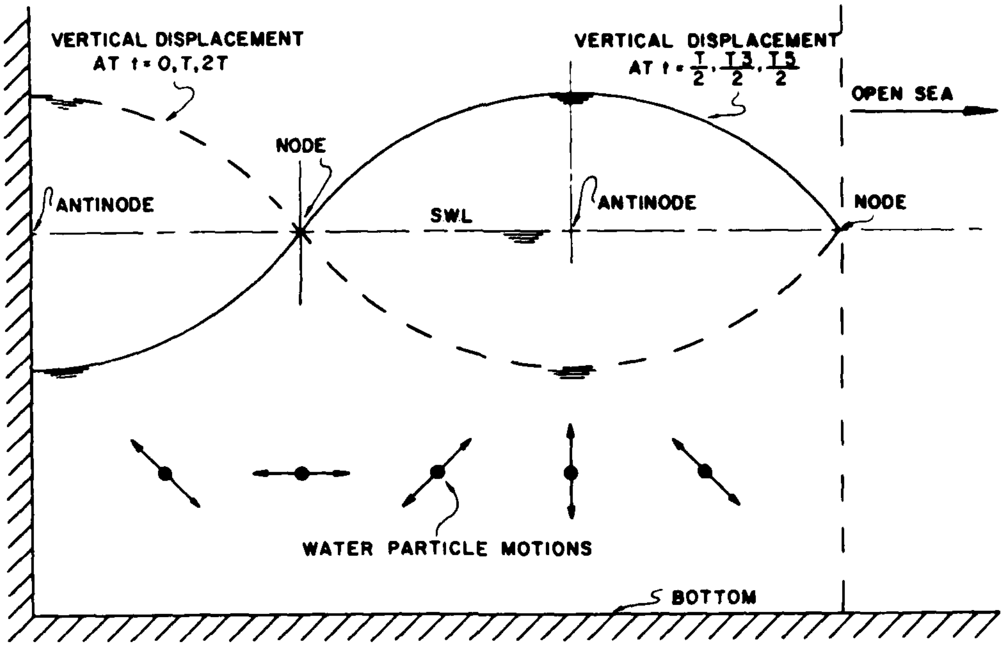


Figure 12. Node, antinode, and water particle motions in a rectangular channel open to the sea, with a node at the entrance channel

not occur for the base plan. Modes of oscillation for representative periods where resonant peaks were defined are shown in Plates 52-56. In general, nodal areas occurred near the entrance, half the channel length or approximately one-third the channel length of East Channel. Maximum horizontal movement occurs in these nodal areas, and adverse ship motion conditions in the channel may continue to exist.

West Channel

22. In West Channel of the Port of Los Angeles, maximum wave height amplifications of 1.9 occurred at 245 sec in the north (closed) end of the basin (gage 5) for the dry bulk export terminal, as opposed to an amplification factor of 4.0 for existing conditions. A second resonant peak and amplification of 0.9 developed for the dry bulk export terminal, but the peak was lower than two adjacent peaks for the base plan. Data for gage 46 in the new West Channel boat basin indicate a maximum wave-height amplification of 2.5 at 82 sec. Test results indicate that wave-height amplification in West Channel would be less severe over the period range tested with the dry bulk export terminal installed in Los Angeles Harbor.

Deep-draft dry bulk export terminal

23. In the proposed deep-draft dry bulk export terminal of the Port of Los Angeles, resonant peaks occurred with wave-height amplification greater than 3.0 at the new berths (gages 19, 22, 23, 25, 35, and 41) for wave periods of 216, 220, and 243 sec. Smaller resonant peaks also occurred for 74-, 91-, 96-, 110-, 119-, 139-, 147-, 167-, 200-, 258-, and 275-sec wave periods at various locations along the new berths. Modes of oscillation for representative resonant periods are shown in Plates 57-66. In general, where nodal areas occur in the proposed dry bulk export terminal, amplification factors are relatively small. Where the amplification factors are larger (greater than 3.0) nodal areas do not occur along the piers. Although the wave-height amplification in the long-period range near the dry bulk terminal is not large over most of the period range tested, the berthing location is exposed to incident wave attack directly through the breakwater entrance.

Southeast Basin

24. In Southeast Basin of the Port of Long Beach, modes of oscillation are affected by the complex geometry of the basin, and resonant modes developed in various sections of the basin which did not extend throughout the entire basin. Small resonant oscillations (amplification less than 3.0) occurred for numerous periods with the Los Angeles dry bulk export terminal installed. In most cases, these peaks corresponded to nearby resonant peaks obtained for existing conditions as shown by the amplification data presented in Plates 28-36. A maximum amplification factor of 7.1 occurred at the north (closed) end of the basin (gage 29) for the 237-sec period, as opposed to a factor of 9.2 for the 226-sec period for existing conditions. Also, a maximum amplification factor of 3.4 developed in Basin Six (gage 33), as opposed to a factor of 4.9 for existing conditions for a 79-sec wave period. Modes of oscillation for representative wave periods are presented in Plates 67-70. Amplification results indicate that the installation of the deep-draft dry bulk export terminal in Los Angeles Harbor would not have a major effect on wave-height amplification in the basin.

East Basin and Back Channel

25. In East Basin of the Port of Long Beach, maximum amplification of 10.4 occurred at gage 42 for a 222-sec wave period with the dry bulk terminal installed. This peak corresponds to an amplification factor of 10.2 for existing conditions for a 224-sec wave period. The only other resonant peak

with an amplification factor that exceeded 3.0 occurred at the 220-sec period at gage 43. With the dry bulk terminal installed, an amplification factor of 4.7 developed at gage 43 versus a factor of 3.7 for existing conditions for 224 sec. In Back Channel (gage 40), a resonant peak with an amplification factor of 5.2 developed for 208 sec for the dry bulk terminal. Existing conditions yielded a resonant peak at 204 sec with an amplification of 4.3. Modes of oscillation for East Basin and Back Channel for representative periods are shown in Plates 71-73. Test results indicated that wave conditions in East Basin and Back Channel with the dry bulk terminal installed would be similar to those for existing conditions.

PART V: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

26. Based on the results of the model investigation reported herein, it is concluded that:

- a. The deep-draft dry bulk export terminal, in general, would result in little change in wave-height amplification throughout the existing harbors' complex.
- b. Wave-height amplification in West Channel of the Port of Los Angeles would decrease with the dry bulk export terminal installed.
- c. Resonant peaks (that do not occur for existing conditions) would develop in East Channel of the Port of Los Angeles with the deep-draft export terminal installed.
- d. Wave-height amplification in Southeast Basin of the Port of Long Beach would be no worse with the Los Angeles dry bulk export terminal installed than for existing conditions.
- e. Although long-period wave-height amplification would be relatively low (maximum of 4.2 at gage 23) near the piers of the proposed Los Angeles deep-draft dry bulk export terminal, the berthing area would be exposed to incident short period wave attack through the breakwater entrance.
- f. Wave-height amplification in East Basin and Back Channel of the Port of Long Beach would not be significantly modified by the installation of the Los Angeles deep-draft dry bulk terminal.

Recommendations

27. It is recommended that either a numerical or experimental moored ship response study be undertaken to adequately quantify moored ship response in Los Angeles and Long Beach Harbors. The effect of changes in wave-height amplification or a shift in period of maximum amplification cannot be readily evaluated until the response functions of the ships using the harbors are known, nor can frequency and duration of adverse ship mooring be determined without frequency of occurrence data for incident long-period waves. Without ship response data, the effect of changes in resonant oscillations in the harbor must be inferred from comparison with existing conditions and from comparison between various berthing areas in the harbor for existing conditions.

REFERENCES

Crosby, L. G., and Durham, D. L. 1975. "Los Angeles and Long Beach Harbors Model Study; Observations of Ship Mooring and Movement." Technical Report H-75-4, Report 2, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Durham, D. L., et al. 1976. "Los Angeles and Long Beach Harbors Model Study; Analyses of Wave and Ship Motion Data," Technical Report H-75-4, Report 3, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Hales, L. Z. 1976. "Transmission of Wave Energy Through and Overtopping of the Long Beach, California, Breakwater; Hydraulic Model Investigation," Miscellaneous Paper H-76-10, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Outlaw, D. G., et al. 1977. "Los Angeles and Long Beach Harbors Model Study; Model Design," Technical Report H-75-4, Report 4, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Outlaw, Douglas G. 1979. "Los Angeles and Long Beach Harbors Model Study; Resonant Response of the Modified Phase I Plan," Technical Report H-75-4, Report 6, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Pickett, E. B., Durham, D. L., and McAnally, W. H., Jr. 1975. "Los Angeles and Long Beach Harbors Model Study; Prototype Data Acquisition and Observations," Technical Report H-75-4, Report 1, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Wilson, B. W., et al. 1968. "Wave and Surge-Action Study for Los Angeles-Long Beach Harbors; Final Report No. 1, prepared by Science Engineering Associates for U. S. Army Engineer District, Los Angeles, Calif.

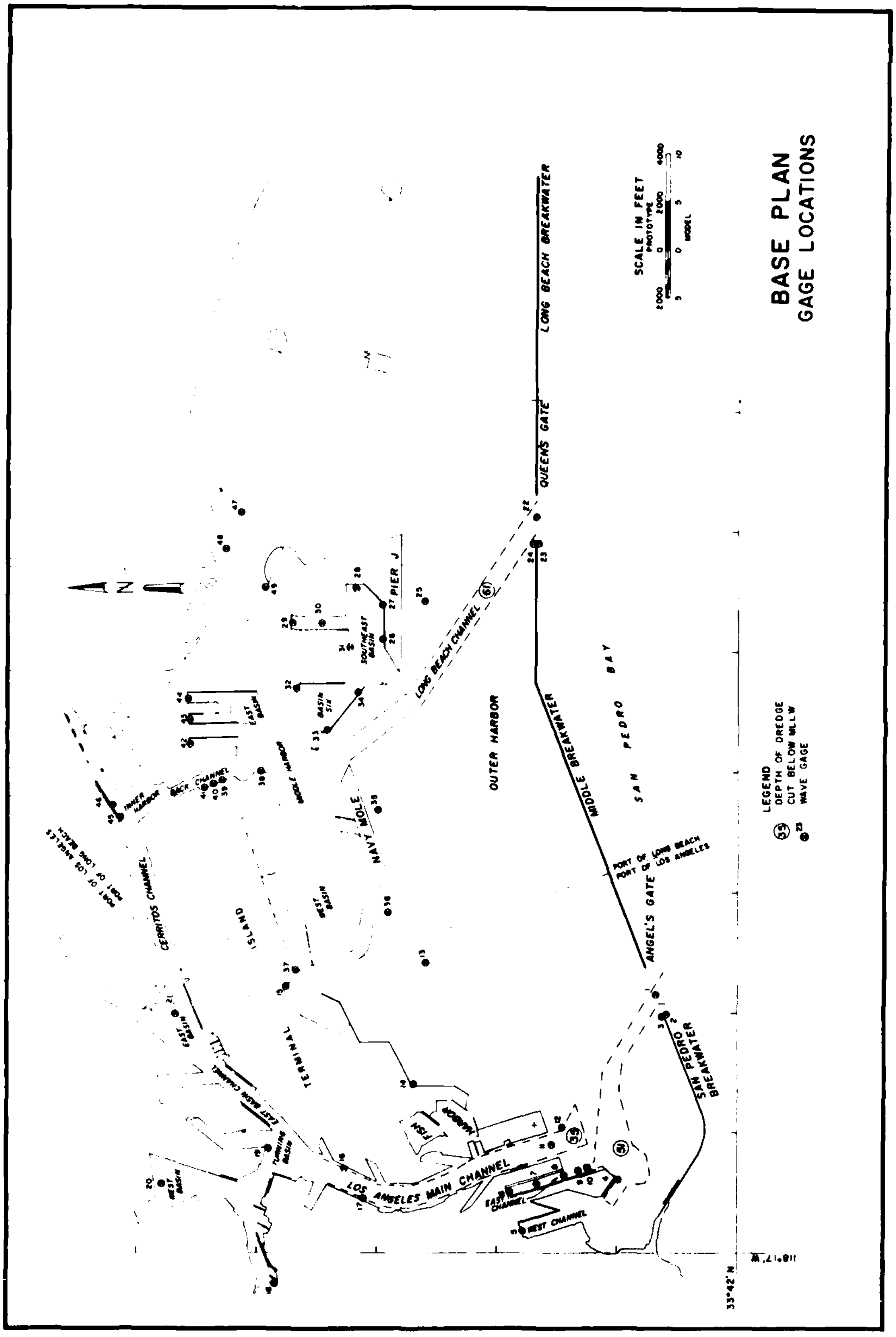

BASE PLAN
GAGE LOCATIONS
SCALE IN FEET
PROTOTYPE
2000 0 2000 4000
MODEL
5 0 5 10
LEGEND
DEPTH OF DREDGE CUT BELOW MLLW
WAVE GAGE
LONG BEACH BREAKWATER
QUEENS GATE
MIDDLE BREAKWATER
SAN PEDRO BAY
OUTER HARBOR
LONG BEACH CHANNEL
PIER J
SOUTHEAST BASIN
BASIN SIX
EAST BASIN
MIDDLE HARBOR
INNER HARBOR
BACK CHANNEL
NAVY MOLE
WEST BASIN
ISLAND
TERMINAL
CERRITOS CHANNEL
PORT OF LOS ANGELES
PORT OF LONG BEACH
ANGEL'S GATE
SAN PEDRO BREAKWATER
LOS ANGELES MAIN CHANNEL
EAST CHANNEL
WEST CHANNEL
FISH HARBOR
EAST BASIN CHANNEL
TURNING BASIN
33°42' N
118°17' W

PLATE 1

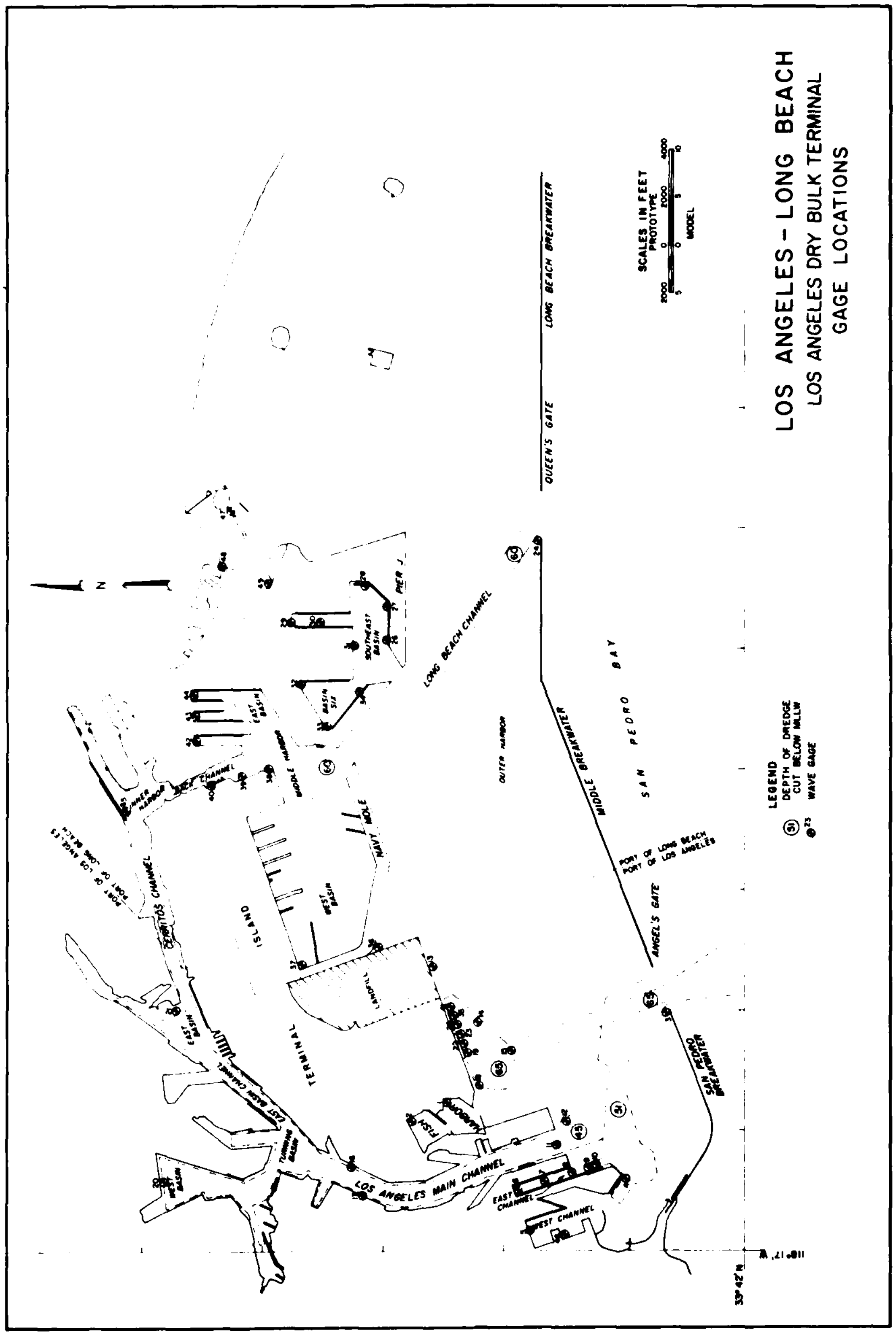
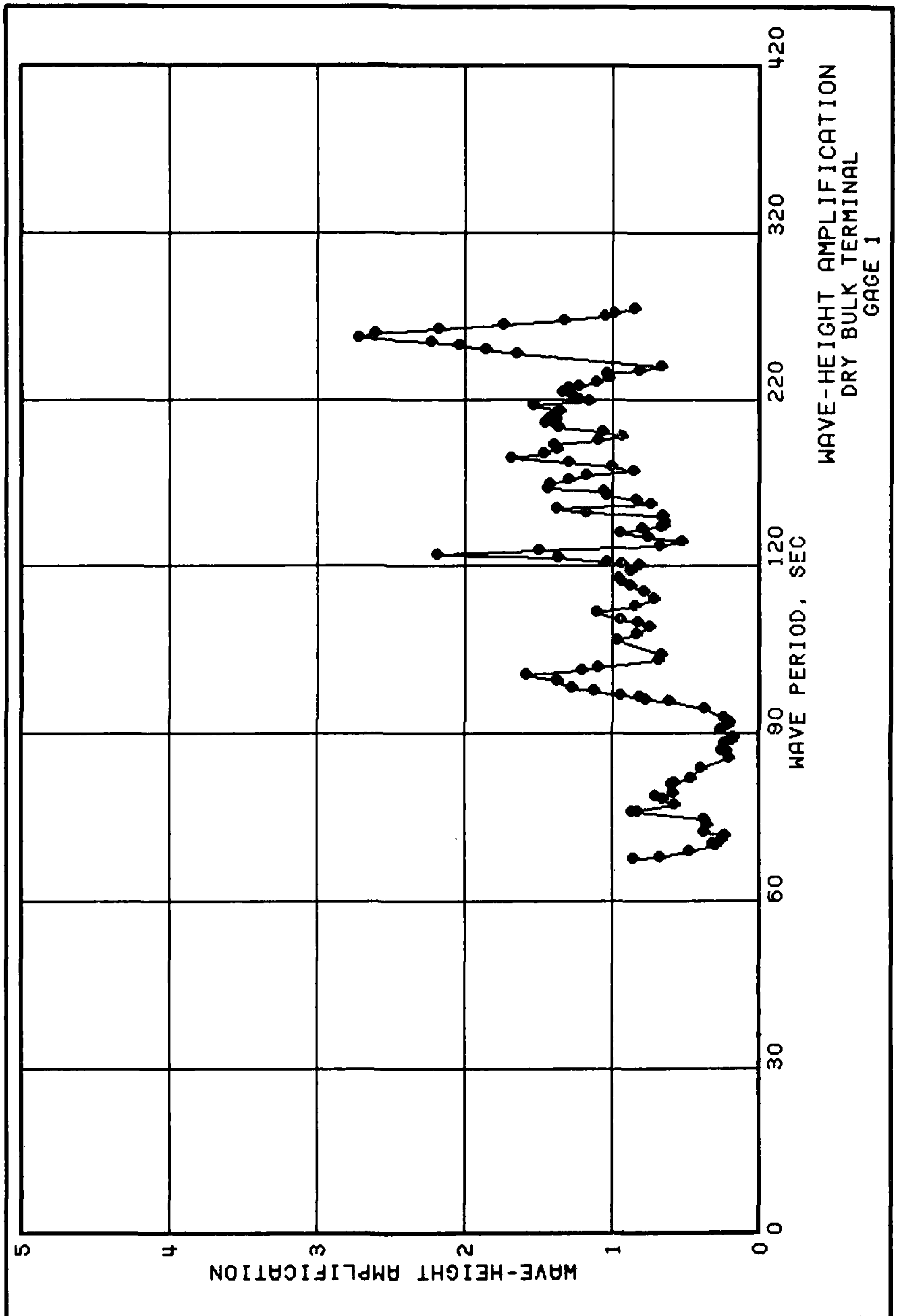

LOS ANGELES - LONG BEACH
LOS ANGELES DRY BULK TERMINAL
GAGE LOCATIONS
SCALES IN FEET
PROTOTYPE
MODEL
LEGEND
DEPTH OF DREDGE CUT BELOW MLLW
WAVE GAGE
LONG BEACH BREAKWATER
QUEEN'S GATE
MIDDLE BREAKWATER
SAN PEDRO BAY
ANGEL'S GATE
SAN PEDRO BREAKWATER
PORT OF LONG BEACH
PORT OF LOS ANGELES
LONG BEACH CHANNEL
OUTER HARBOR
NAVY MOLE
MIDDLE HARBOR
EAST BASIN
BASIN SIX
SOUTHEAST BASIN
PIER J
WEST BASIN
ISLAND
TERMINAL
LANDFILL
CERRITOS CHANNEL
INNER HARBOR
EAST BASIN CHANNEL
TURNING BASIN
LOS ANGELES MAIN CHANNEL
EAST CHANNEL
WEST CHANNEL
33°42' N
118°17' W

PLATE 2


WAVE-HEIGHT AMPLIFICATION
DRY BULK TERMINAL
GAGE 1
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
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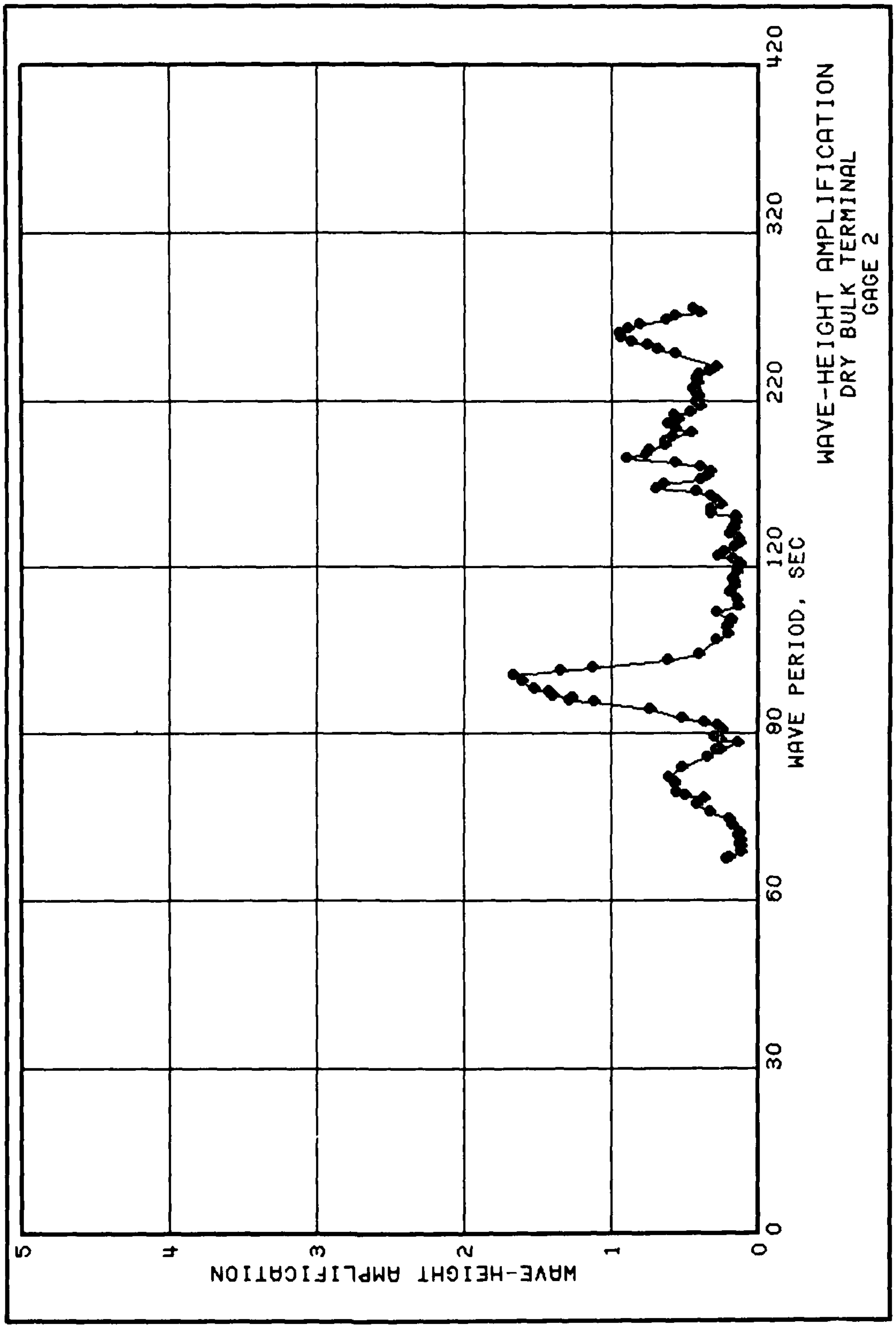
30
60
90
120
220
320
420
0
1
2
3
4
5



WAVE-HEIGHT AMPLIFICATION
DRY BULK TERMINAL
GAGE 2
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
0
30
60
90
120
220
320
420
0
1
2
3
4
5

PLATE 4

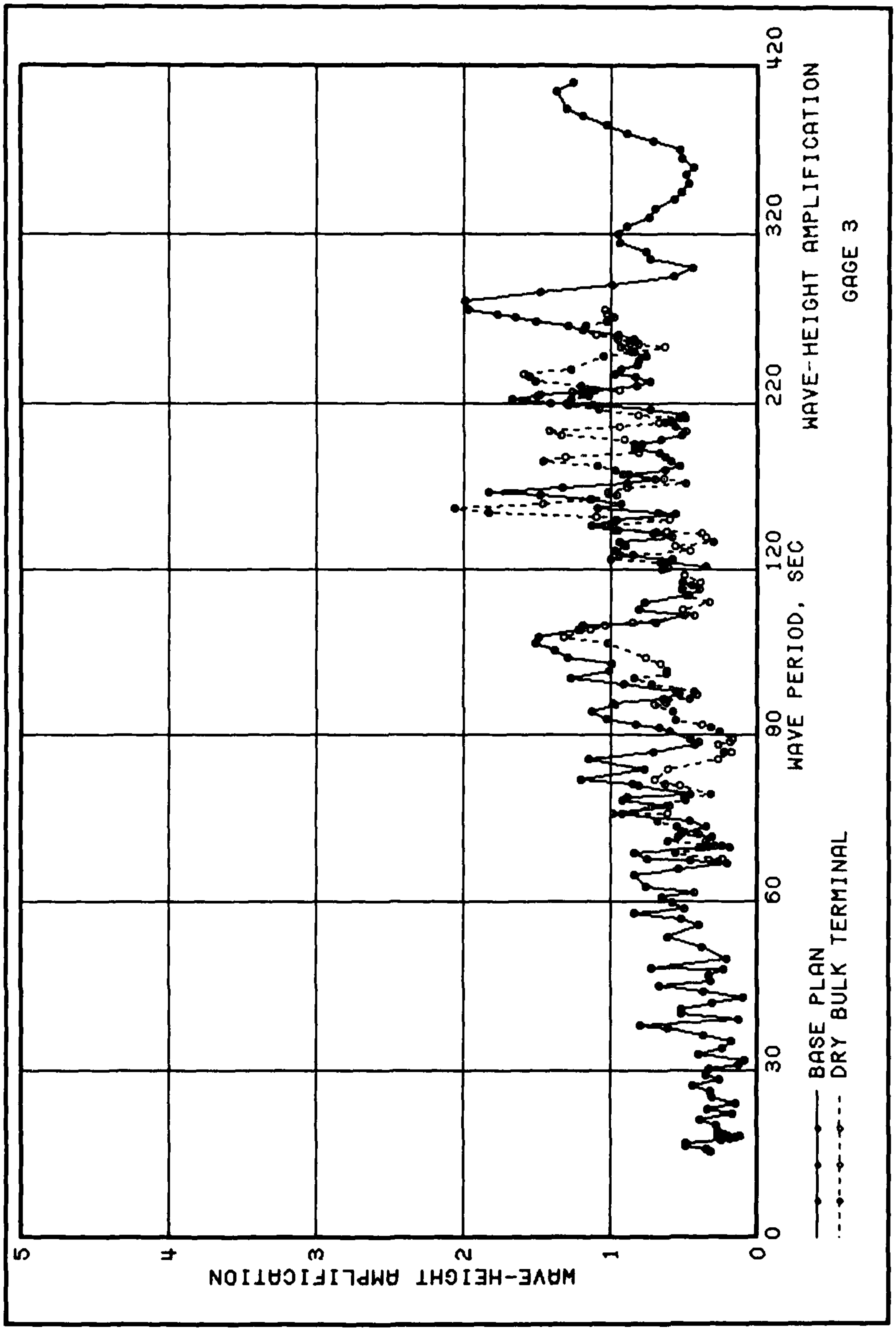
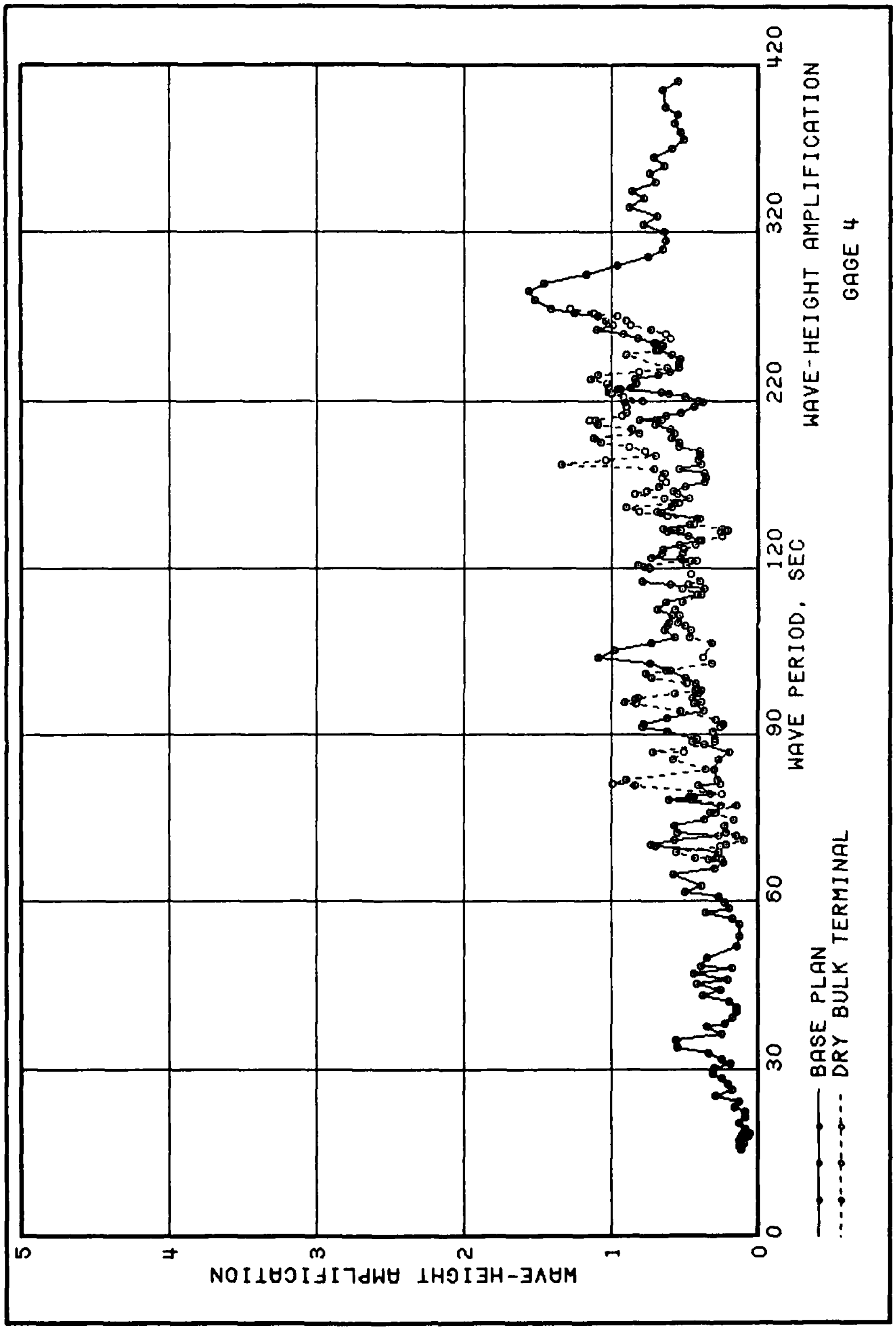

WAVE-HEIGHT AMPLIFICATION
GAGE 3
WAVE-HEIGHT AMPLIFICATION
WAVE PERIOD, SEC
0
1
2
3
4
5
0
30
60
90
120
220
320
420
BASE PLAN
DRY BULK TERMINAL

PLATE 5



WAVE-HEIGHT AMPLIFICATION
GAGE 4
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
BASE PLAN
DRY BULK TERMINAL
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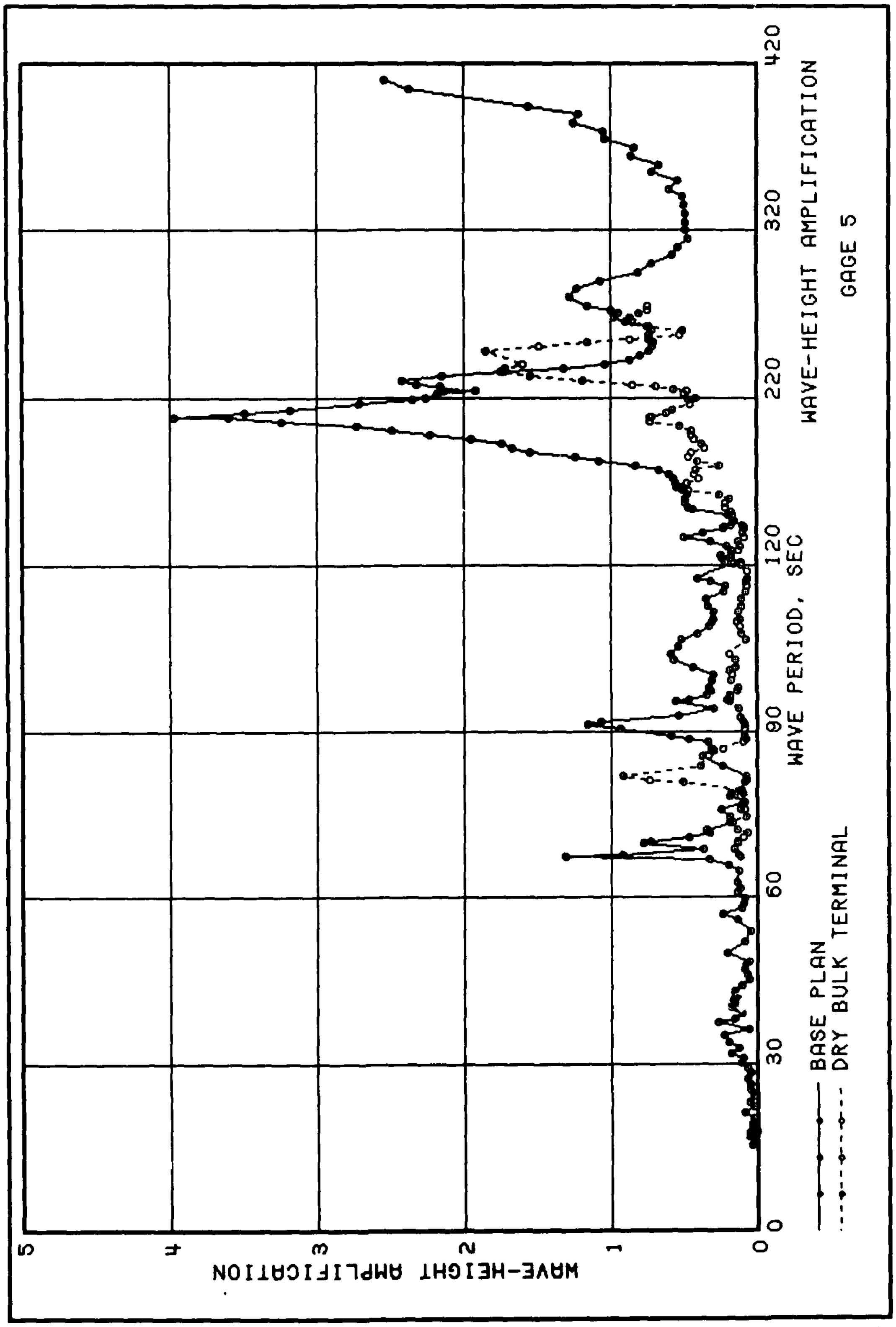
30
60
90
120
220
320
420
0
1
2
3
4
5

PLATE 6


WAVE-HEIGHT AMPLIFICATION
GAGE 5
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
BASE PLAN
DRY BULK TERMINAL
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30
60
90
120
220
320
420
0
1
2
3
4
5

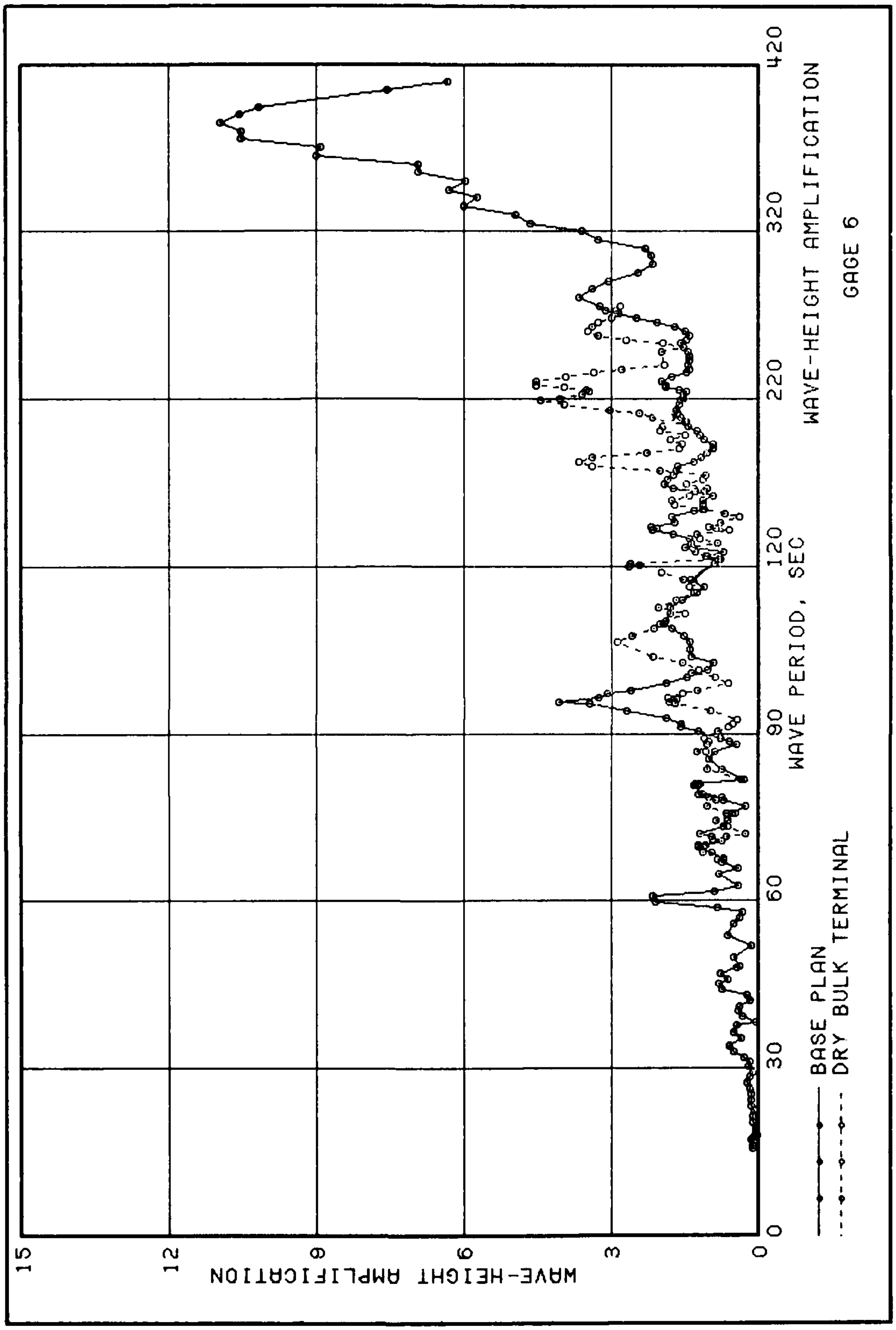

WAVE-HEIGHT AMPLIFICATION
GAGE 6
WAVE PERIOD, SEC
0
30
60
90
120
220
320
420
WAVE-HEIGHT AMPLIFICATION
0
3
6
9
12
15
BASE PLAN
DRY BULK TERMINAL

PLATE 8

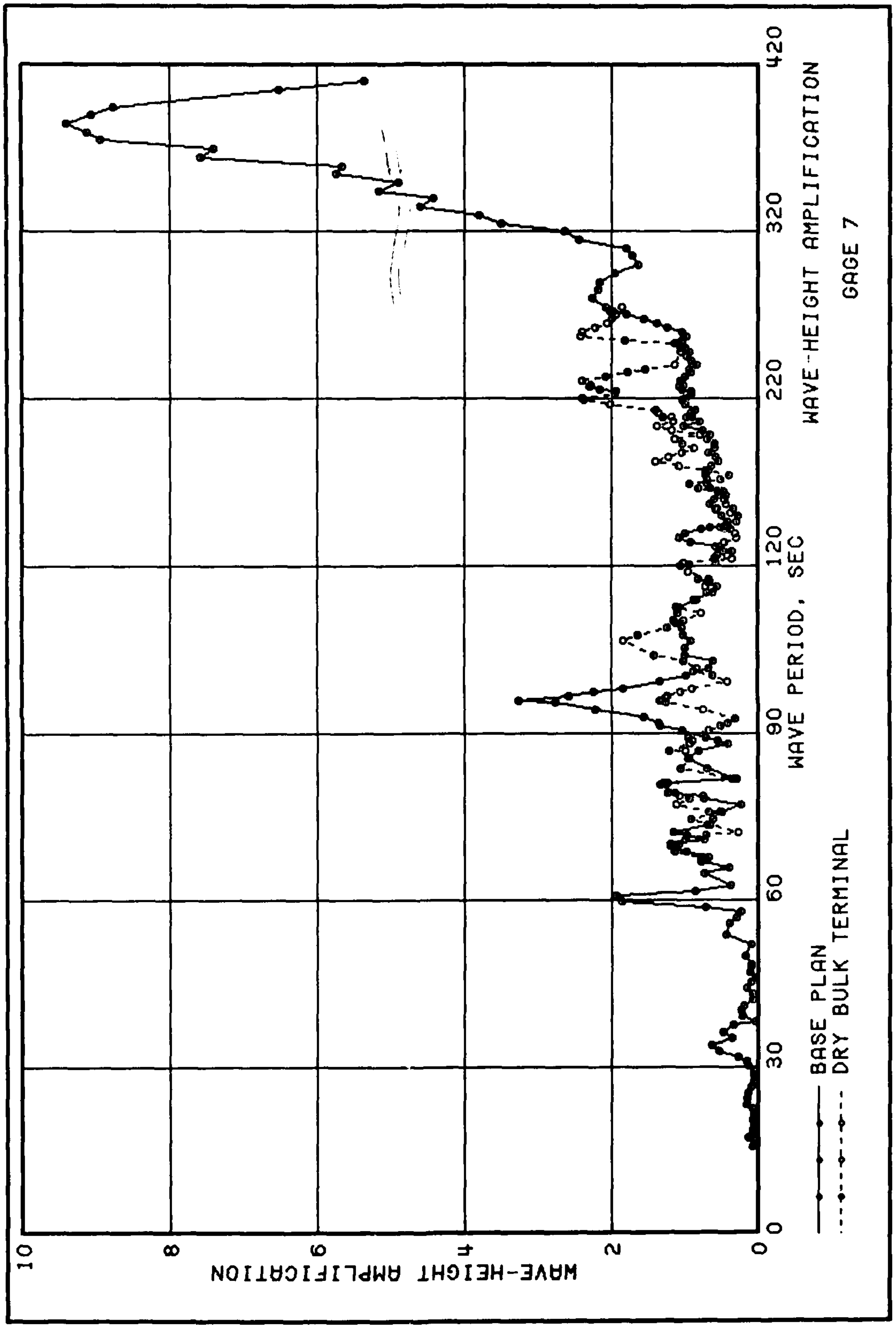
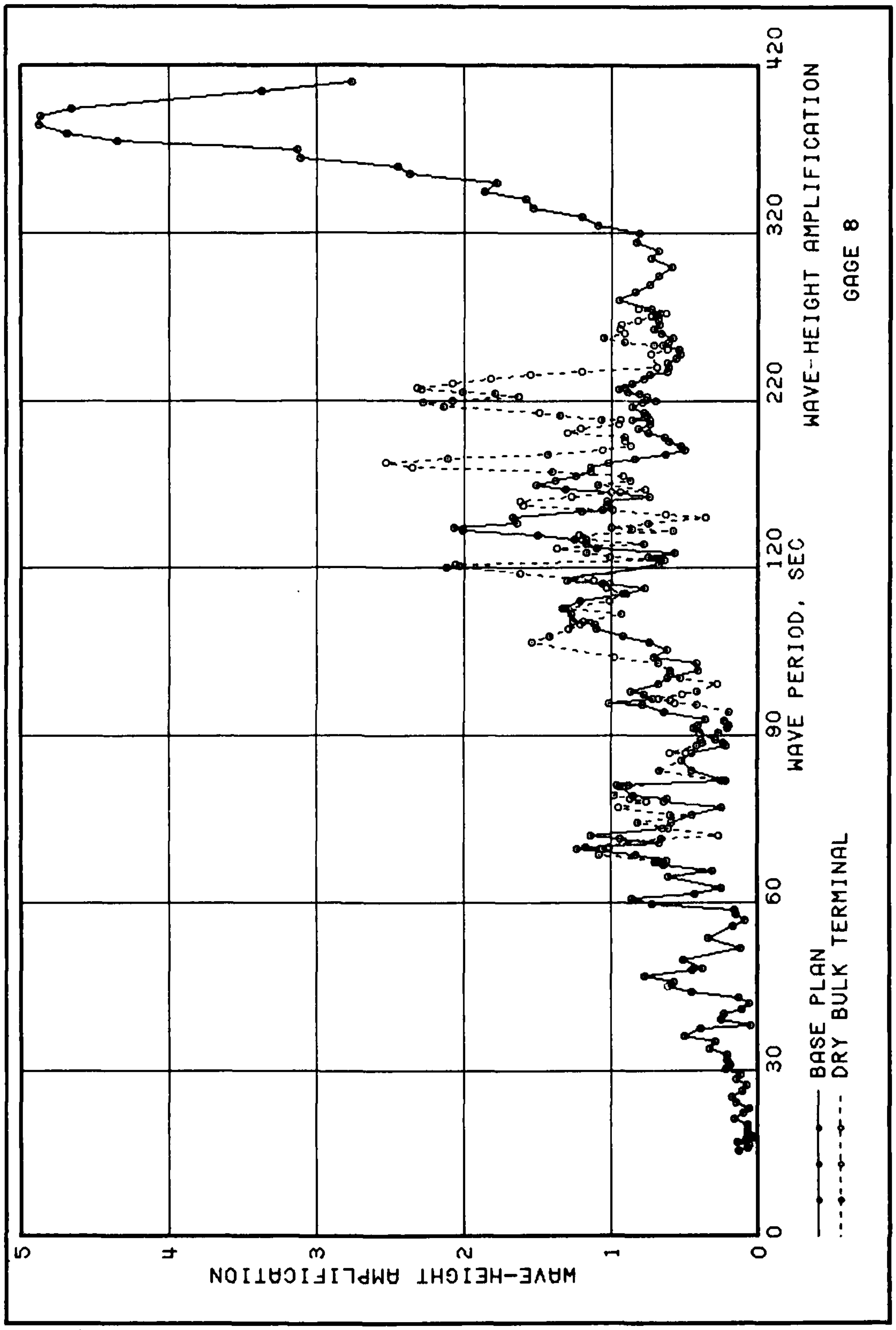

WAVE-HEIGHT AMPLIFICATION
GAGE 7
WAVE PERIOD, SEC
0
30
60
90
120
220
320
420
WAVE-HEIGHT AMPLIFICATION
0
2
4
6
8
10
BASE PLAN
DRY BULK TERMINAL

PLATE 9



WAVE-HEIGHT AMPLIFICATION
GAGE 8
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
BASE PLAN
DRY BULK TERMINAL
0
30
60
90
120
220
320
420
0
1
2
3
4
5

PLATE 10

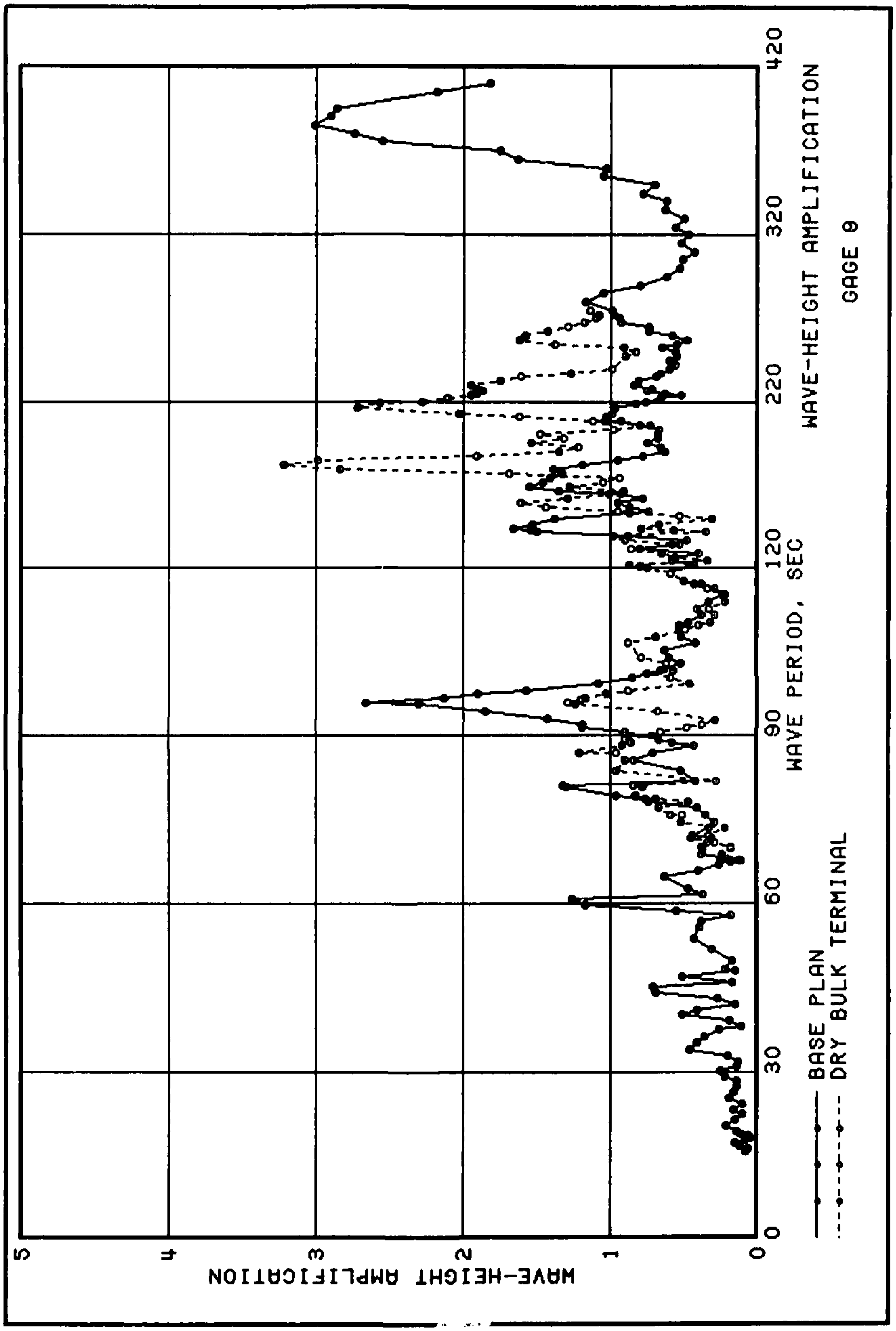

WAVE-HEIGHT AMPLIFICATION
GAGE 9
WAVE-HEIGHT AMPLIFICATION
WAVE PERIOD, SEC
0
1
2
3
4
5
30
60
90
120
220
320
420
BASE PLAN
DRY BULK TERMINAL

PLATE 11

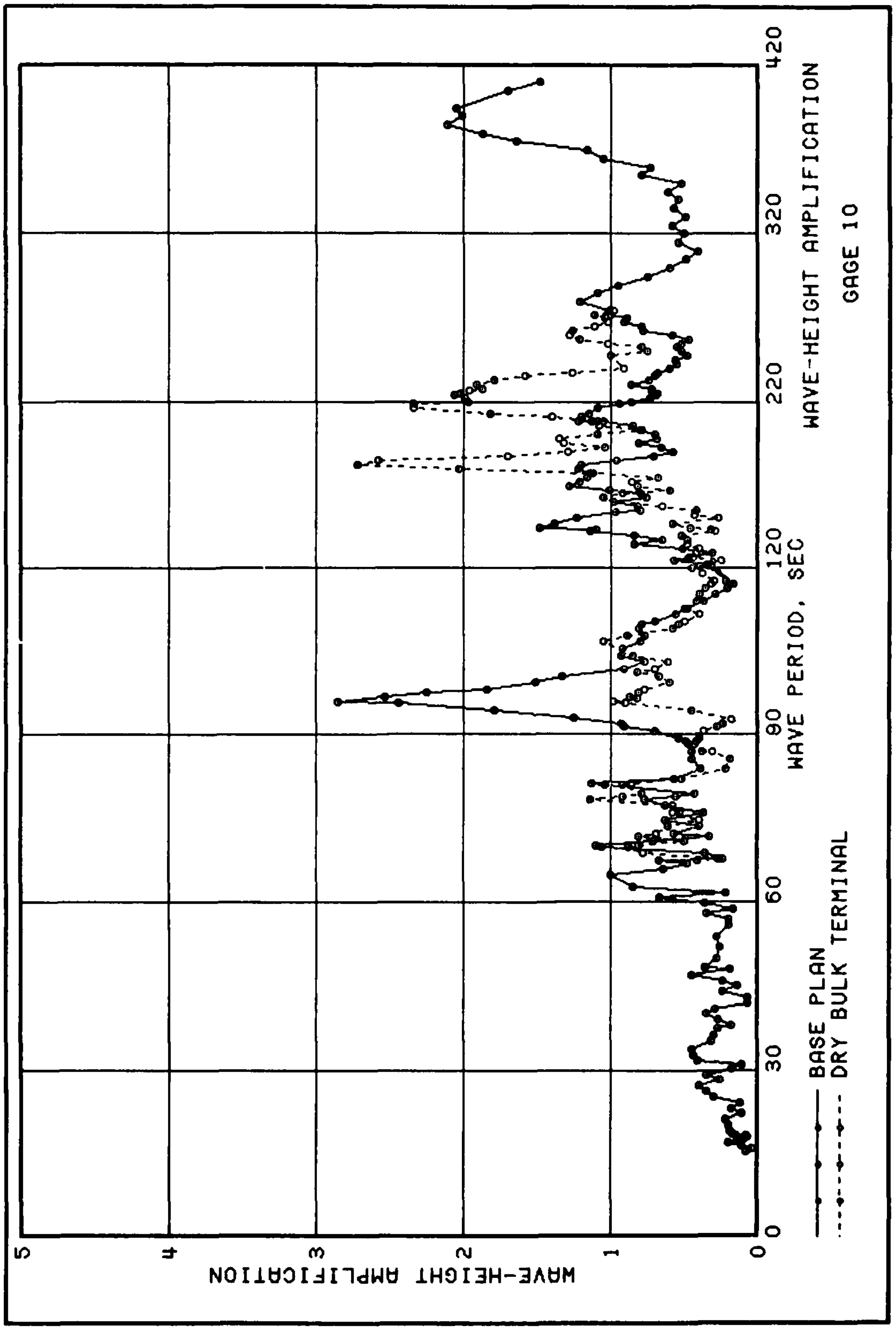

WAVE-HEIGHT AMPLIFICATION
GAGE 10
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
0
30
60
90
120
220
320
420
0
1
2
3
4
5
BASE PLAN
DRY BULK TERMINAL

PLATE 12

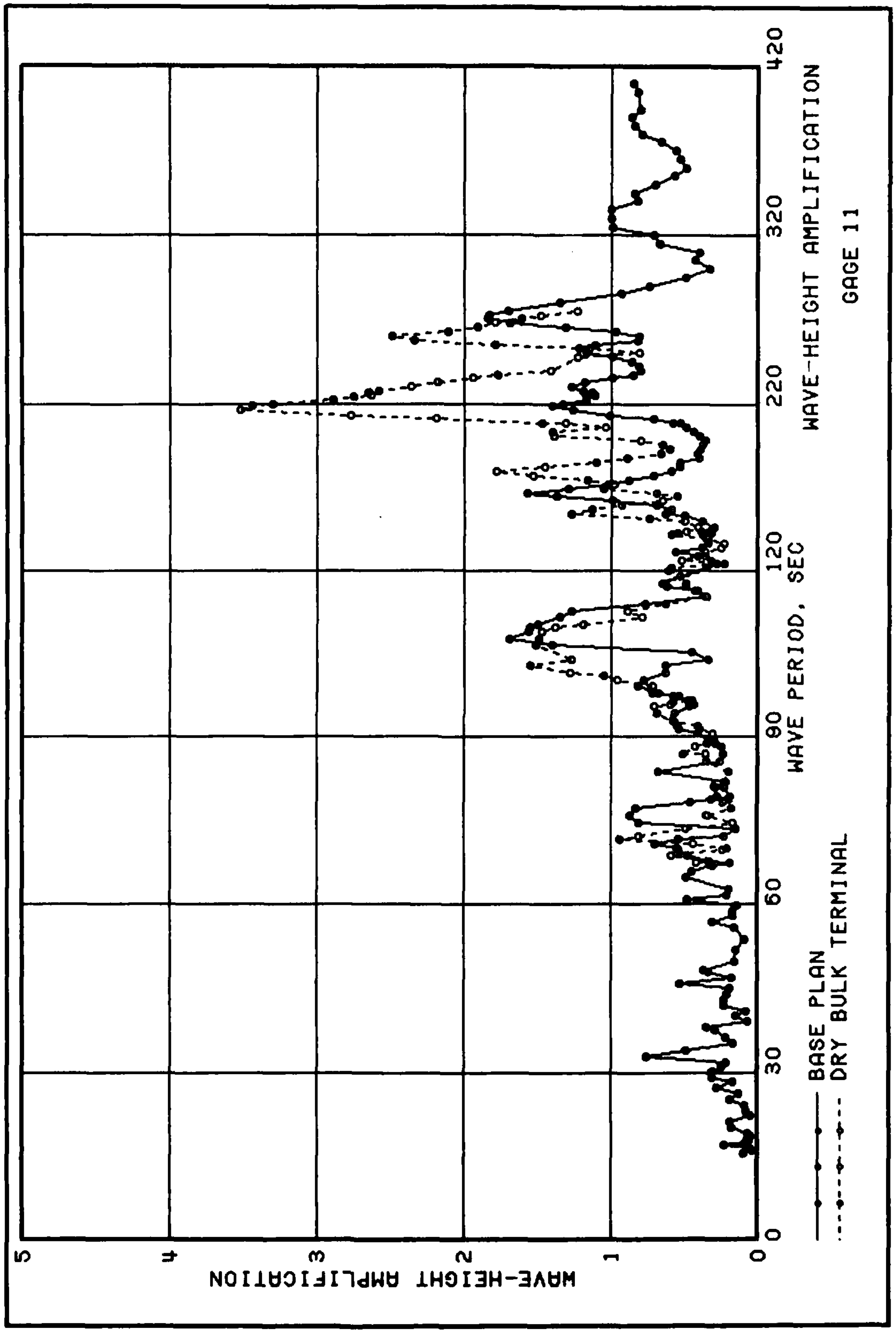

WAVE-HEIGHT AMPLIFICATION
GAGE 11
WAVE-HEIGHT AMPLIFICATION
WAVE PERIOD, SEC
0
30
60
90
120
220
320
420
0
1
2
3
4
5
BASE PLAN
DRY BULK TERMINAL

PLATE 13

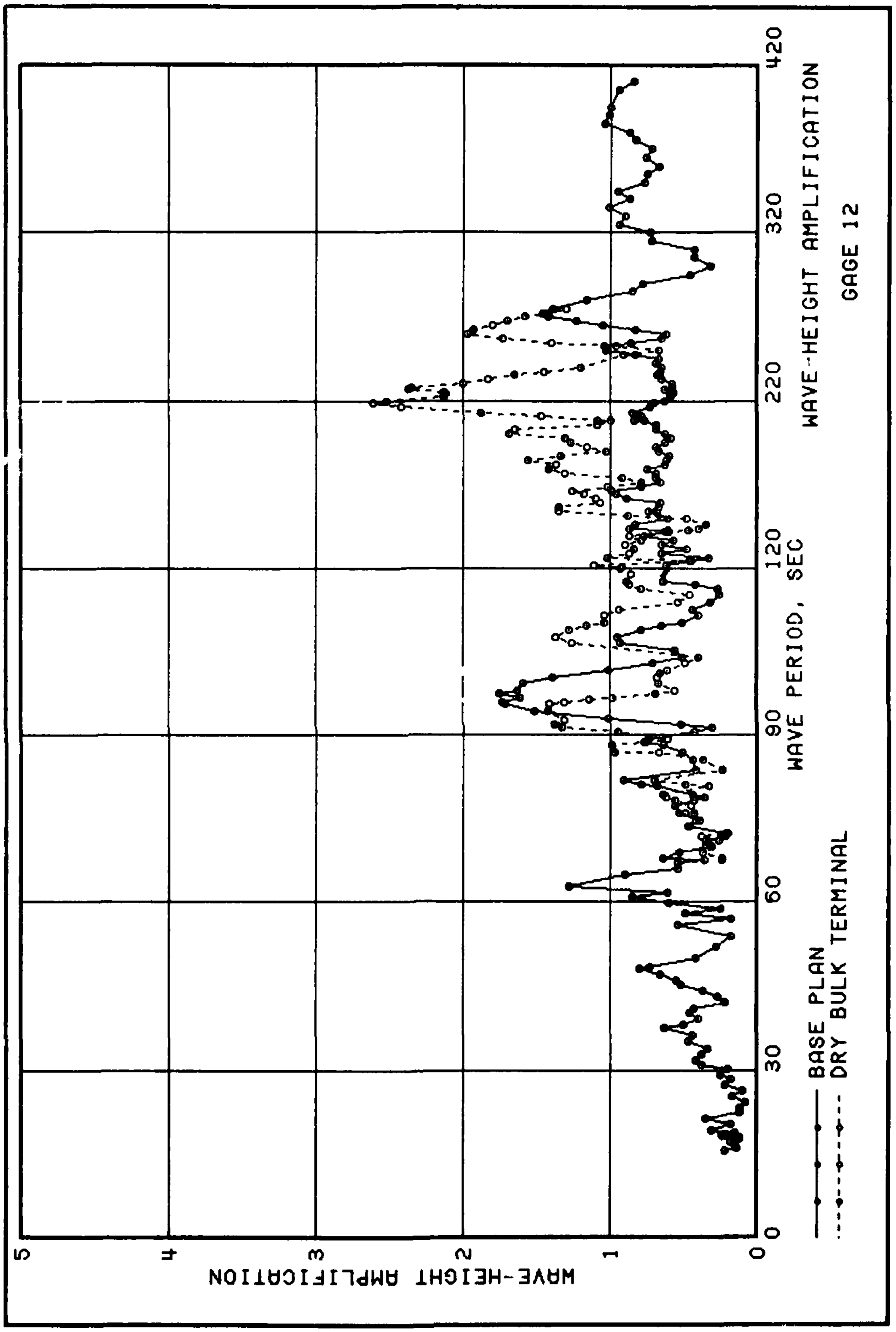
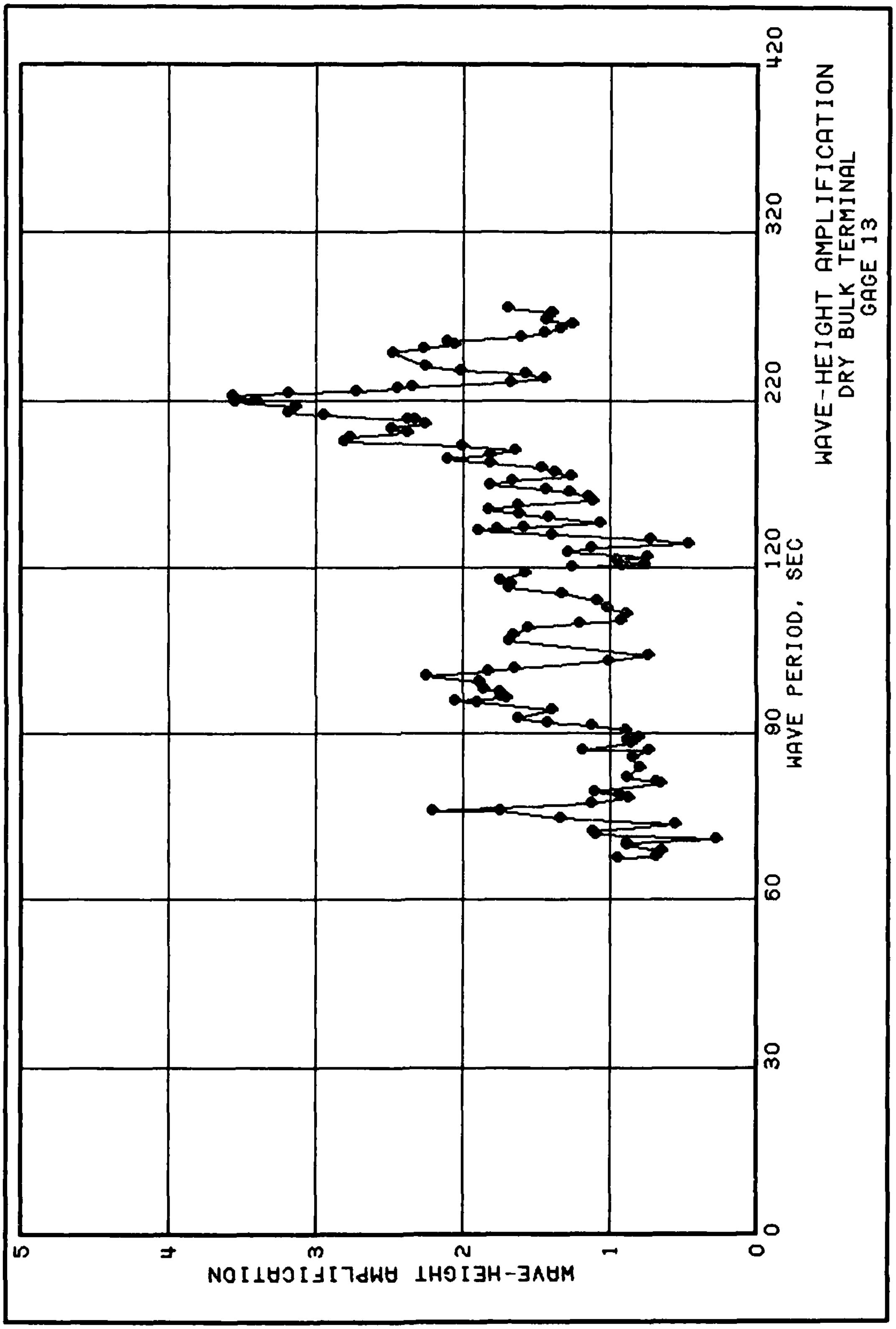

WAVE-HEIGHT AMPLIFICATION
GAGE 12
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
0
1
2
3
4
5
0
30
60
90
120
220
320
420
BASE PLAN
DRY BULK TERMINAL

PLATE 14


WAVE-HEIGHT AMPLIFICATION
DRY BULK TERMINAL
GAGE 13
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
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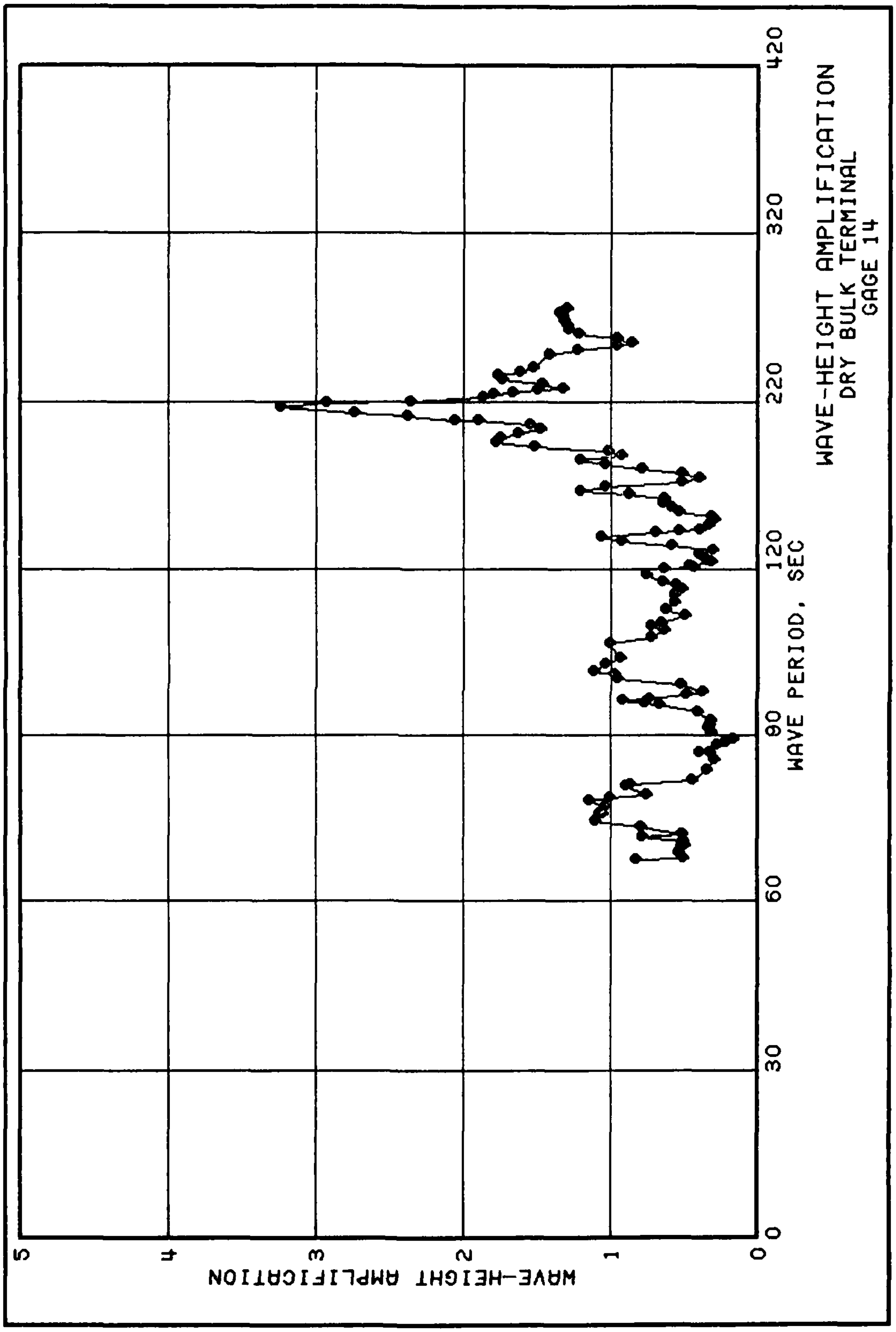
30
60
90
120
220
320
420
0
1
2
3
4
5


WAVE-HEIGHT AMPLIFICATION
DRY BULK TERMINAL
GAGE 14
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
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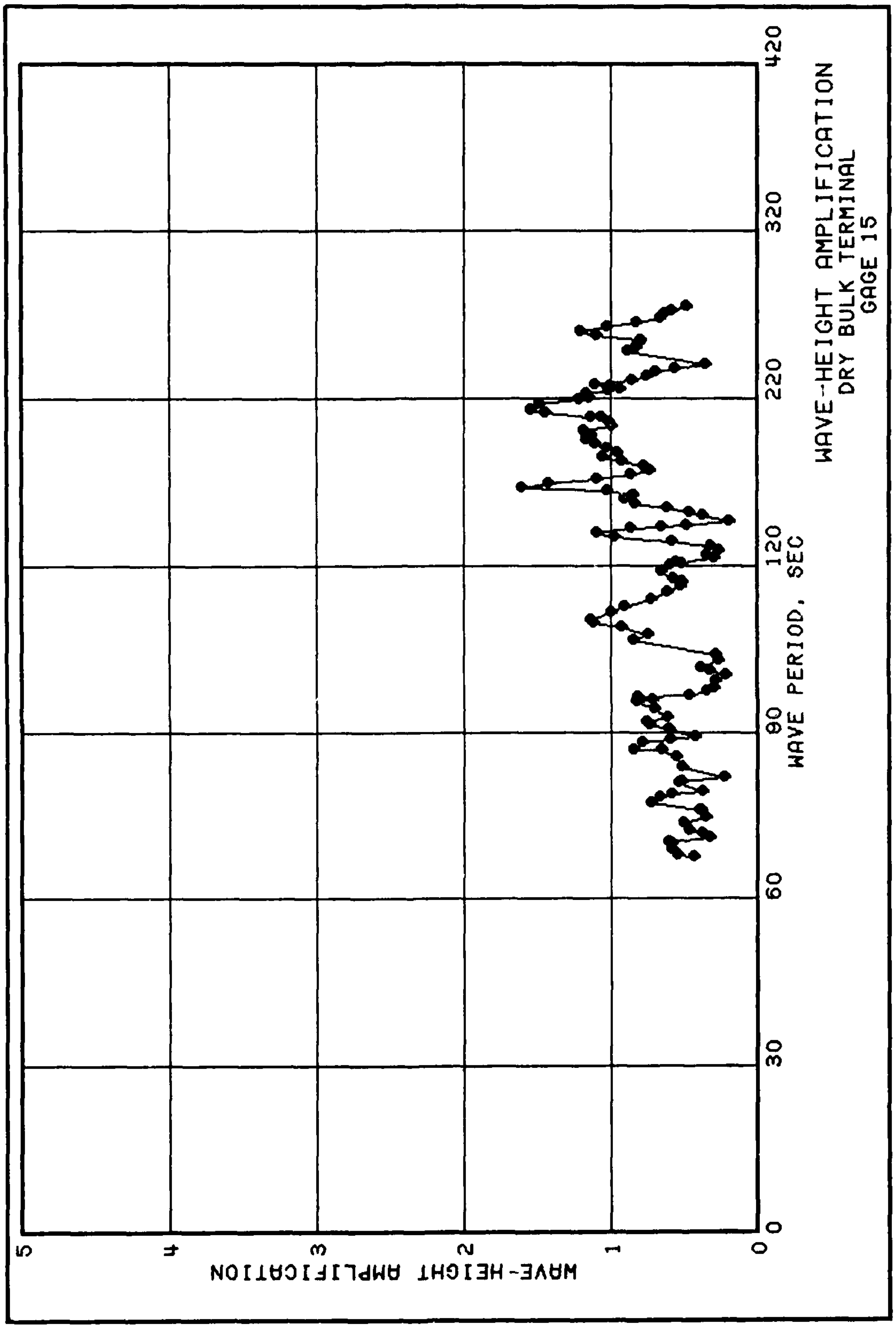
30
60
90
120
220
320
420
0
1
2
3
4
5

PLATE 16


WAVE-HEIGHT AMPLIFICATION
DRY BULK TERMINAL
GAGE 15
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
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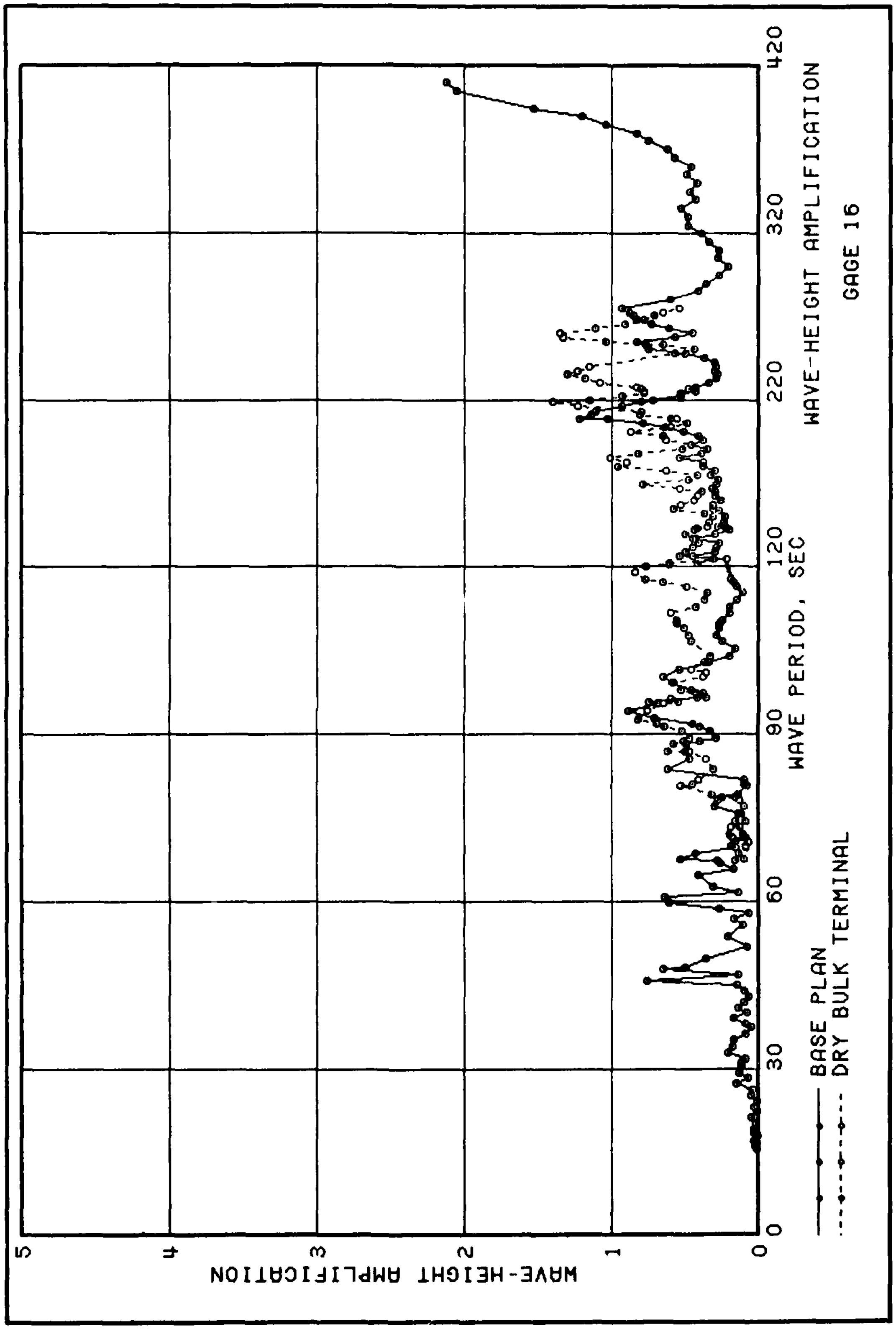
30
60
90
120
220
320
420
0
1
2
3
4
5

PLATE 17



WAVE-HEIGHT AMPLIFICATION
GAGE 16
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
BASE PLAN
DRY BULK TERMINAL
0
30
60
90
120
220
320
420
0
1
2
3
4
5

PLATE 18

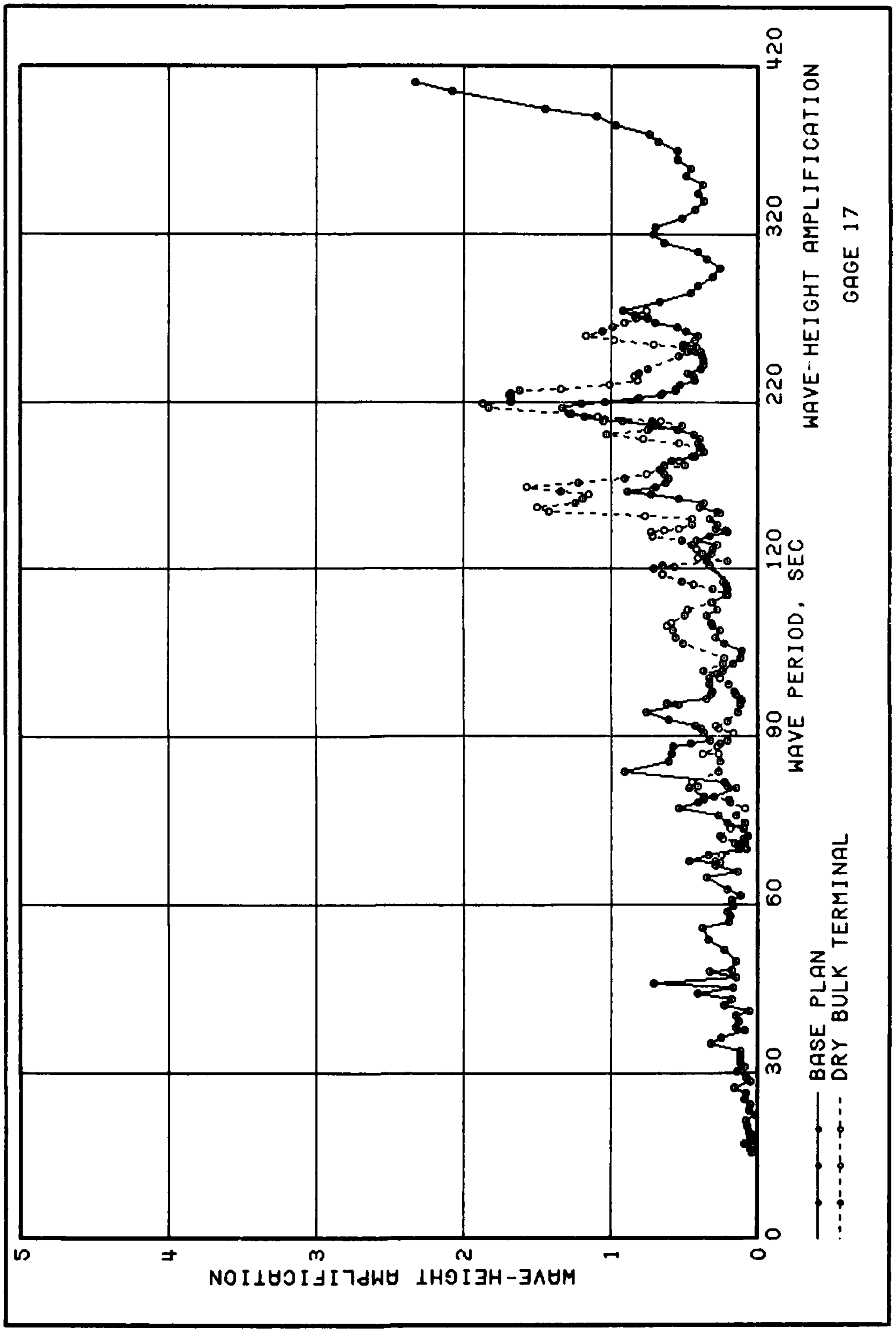
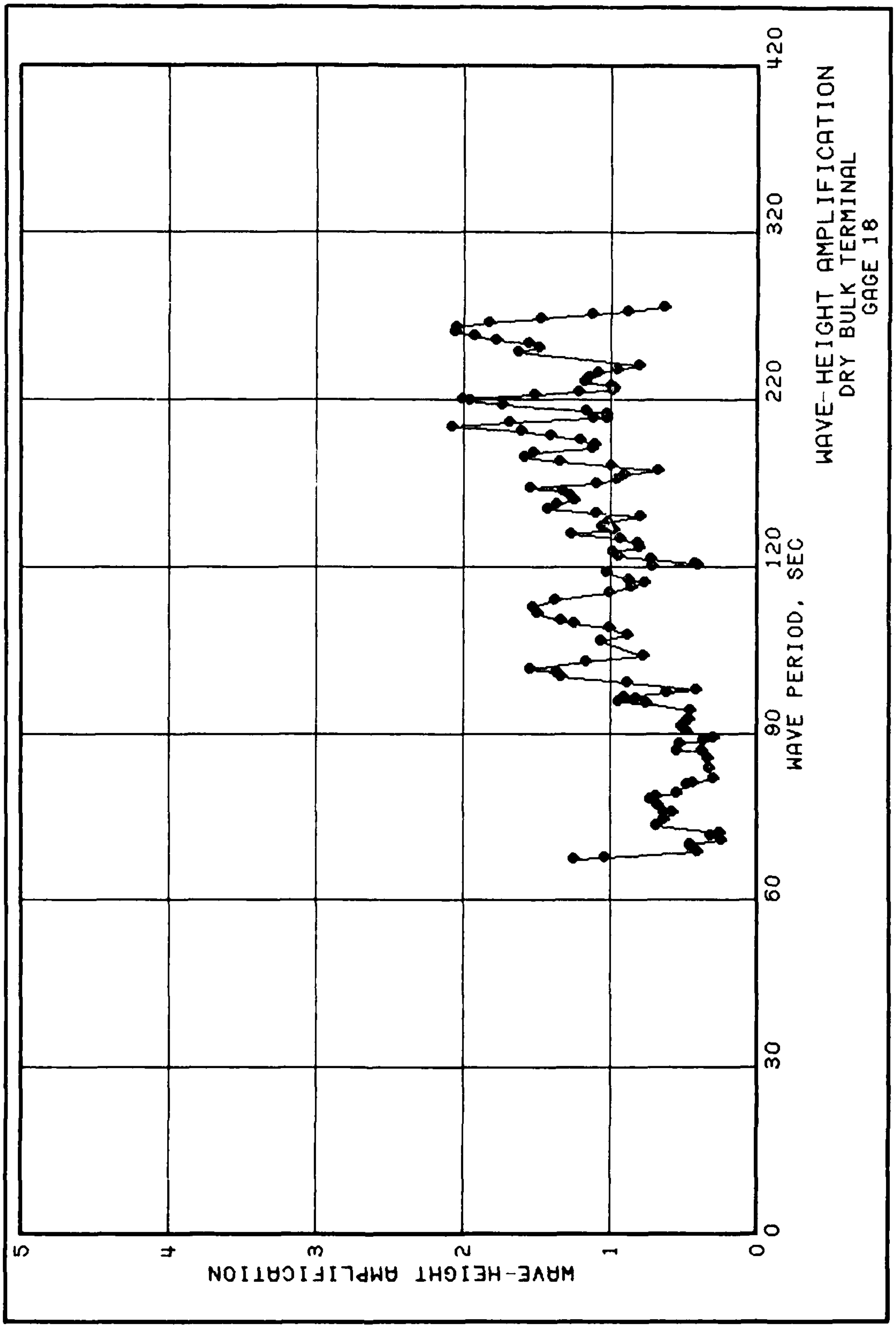

WAVE-HEIGHT AMPLIFICATION
GAGE 17
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
BASE PLAN
DRY BULK TERMINAL
0
30
60
90
120
220
320
420
0
1
2
3
4
5

PLATE 19


WAVE-HEIGHT AMPLIFICATION
DRY BULK TERMINAL
GAGE 18
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
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30
60
90
120
220
320
420
0
1
2
3
4
5

PLATE 20

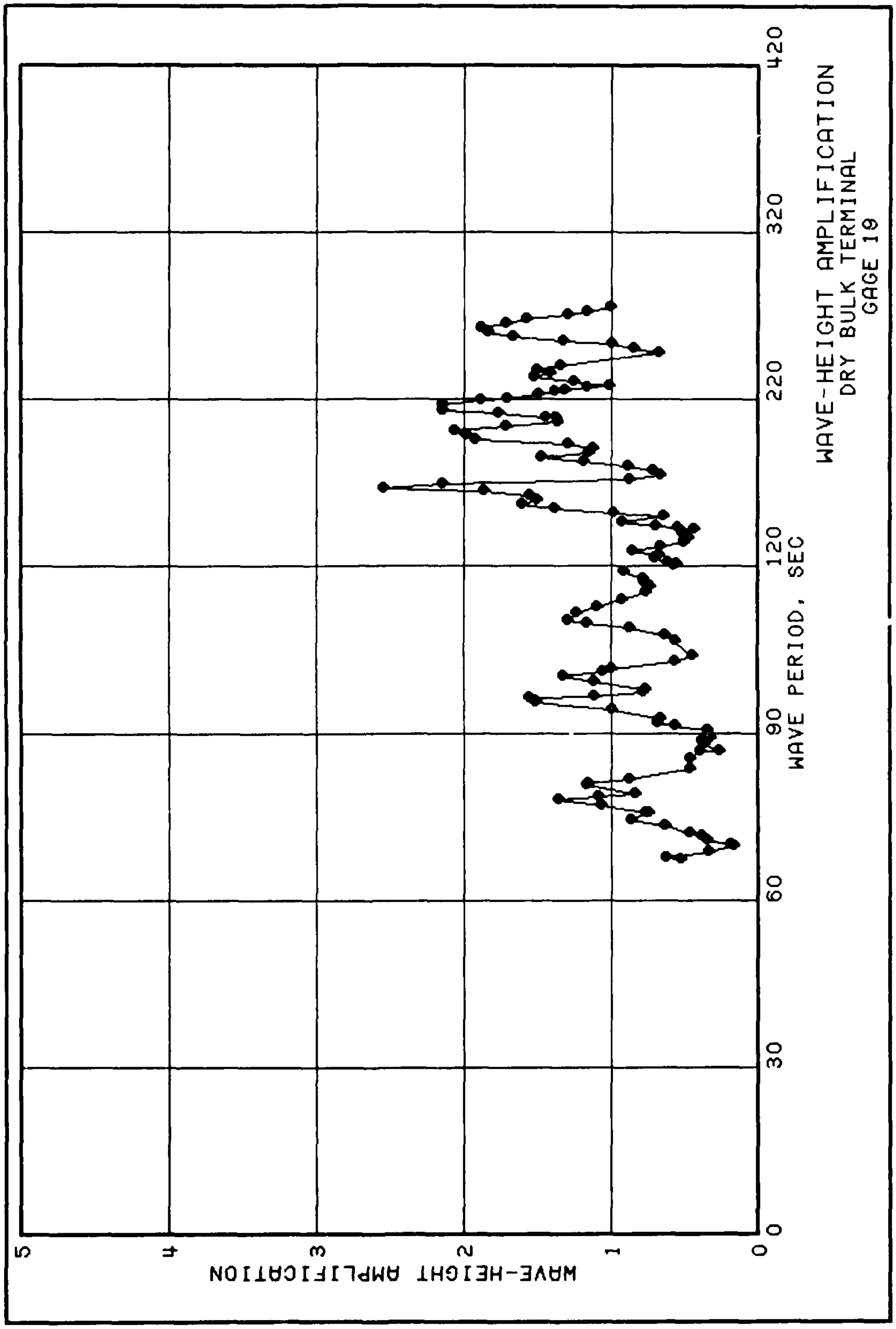

WAVE-HEIGHT AMPLIFICATION
DRY BULK TERMINAL
GAGE 19
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
0
30
60
90
120
220
320
420
0
1
2
3
4
5

PLATE 21

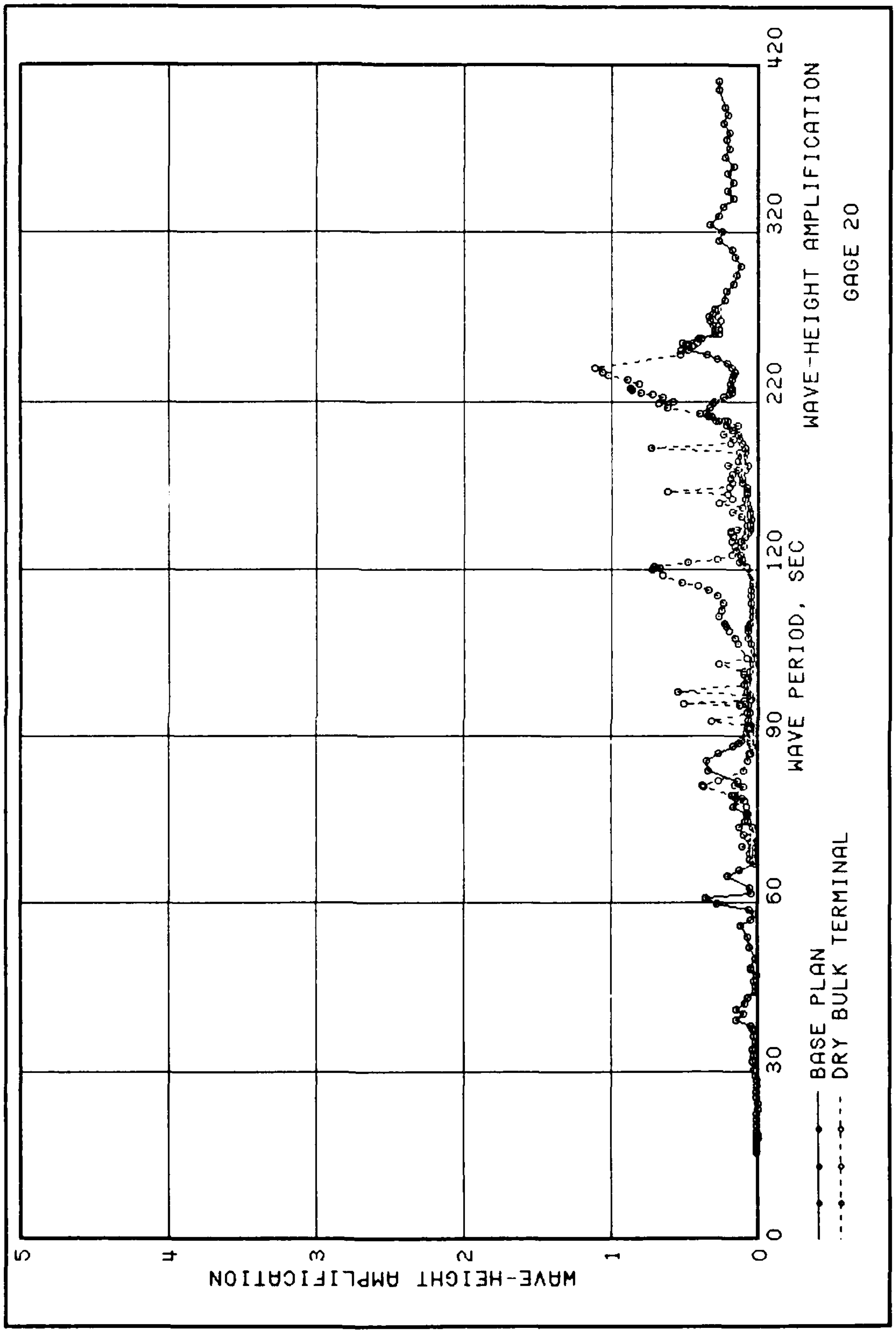
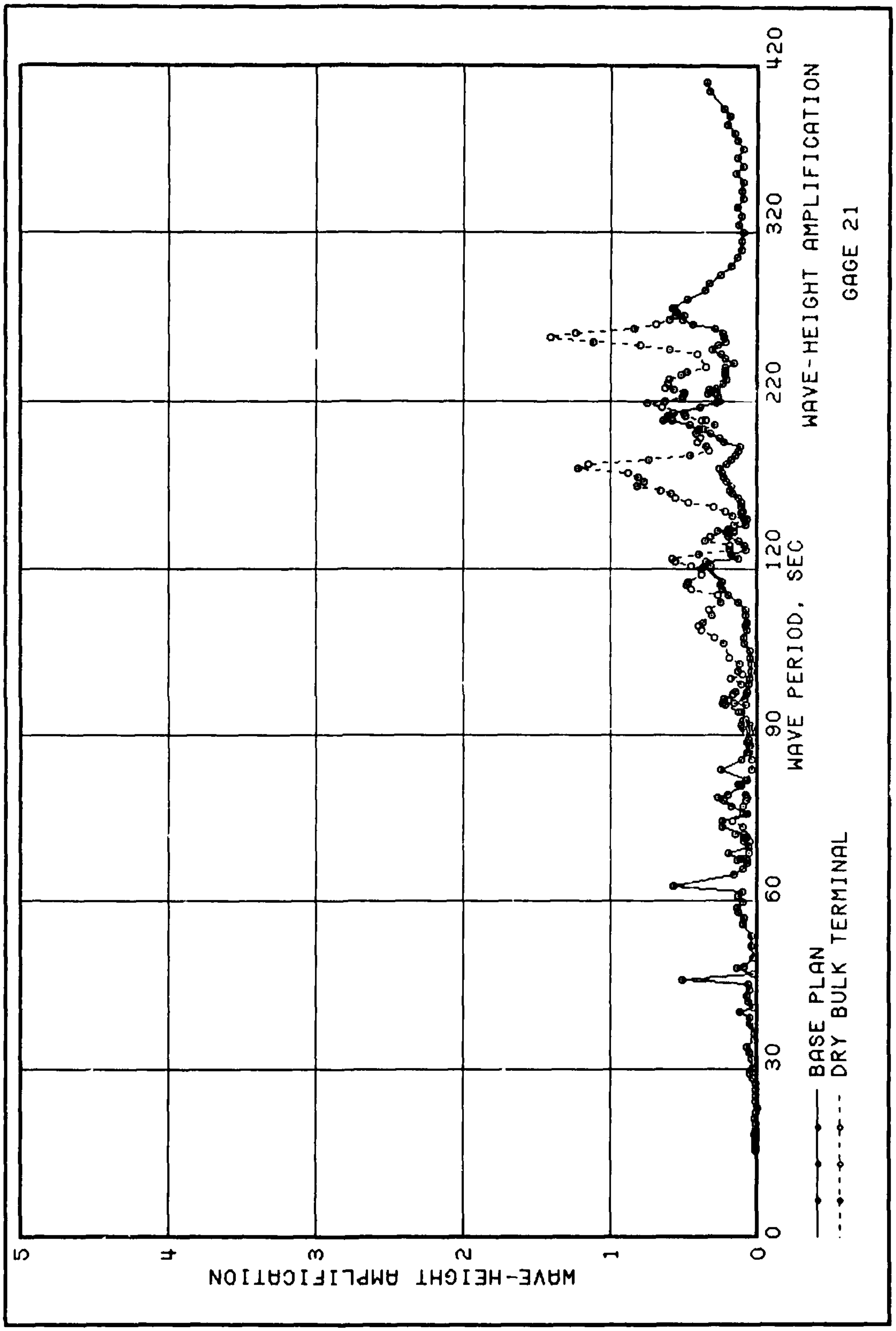

WAVE-HEIGHT AMPLIFICATION
GAGE 20
WAVE PERIOD, SEC
0
30
60
90
120
220
320
420
WAVE-HEIGHT AMPLIFICATION
0
1
2
3
4
5
BASE PLAN
DRY BULK TERMINAL

PLATE 22


WAVE-HEIGHT AMPLIFICATION
GAGE 21
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
BASE PLAN
DRY BULK TERMINAL
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30
60
90
120
220
320
420
0
1
2
3
4
5

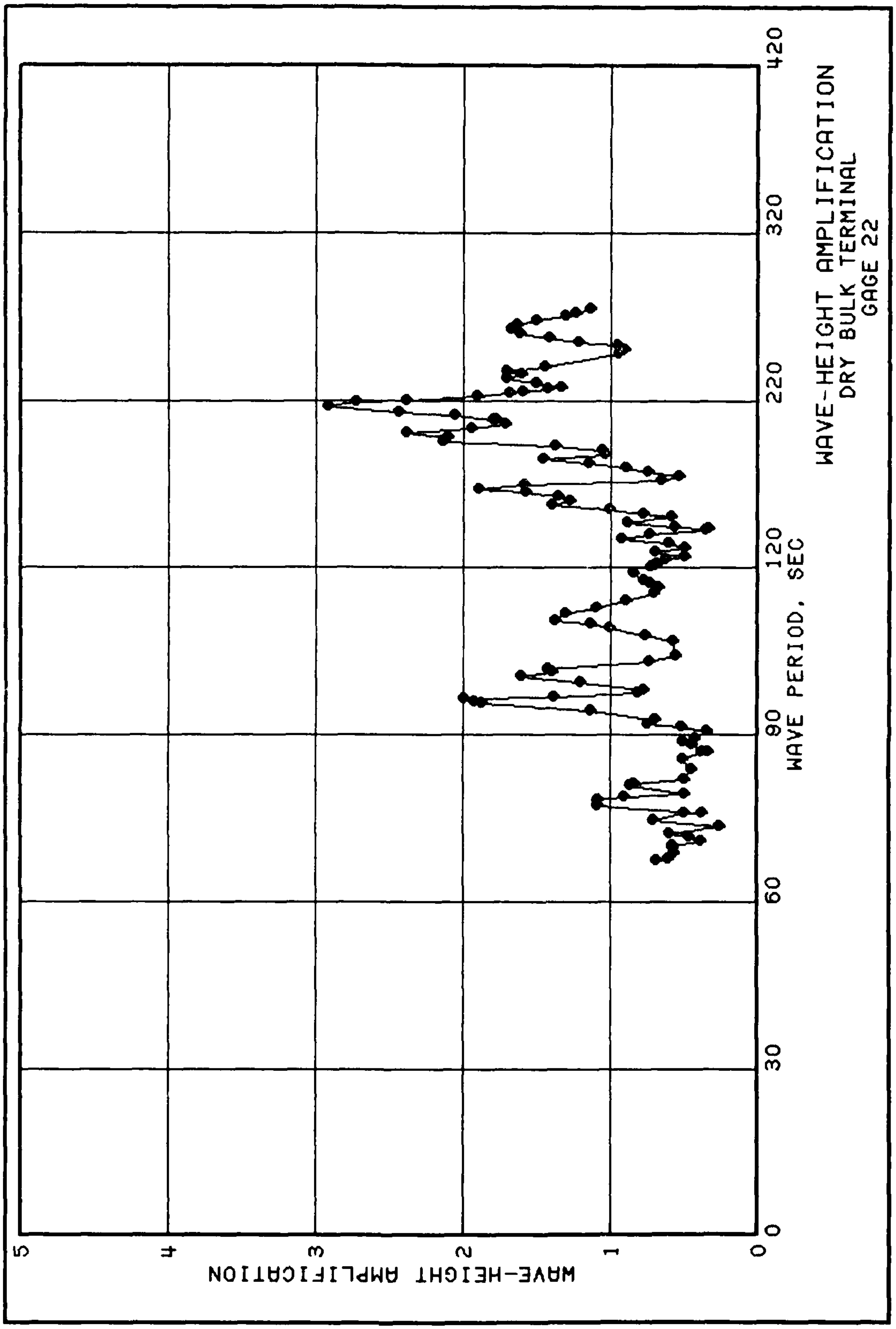
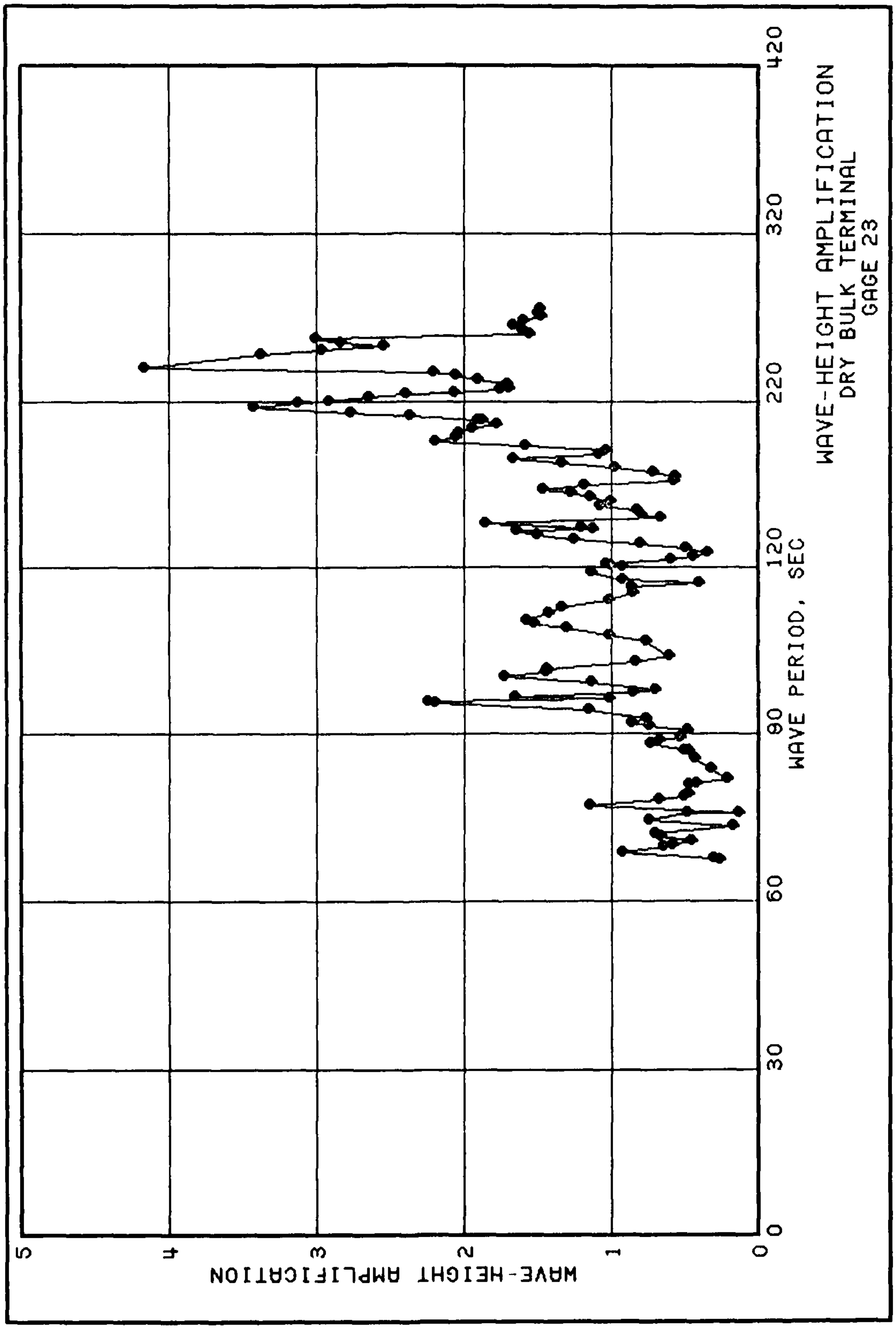

WAVE-HEIGHT AMPLIFICATION
DRY BULK TERMINAL
GAGE 22
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
0
30
60
90
120
220
320
420
0
1
2
3
4
5

PLATE 24


WAVE-HEIGHT AMPLIFICATION
DRY BULK TERMINAL
GAGE 23
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
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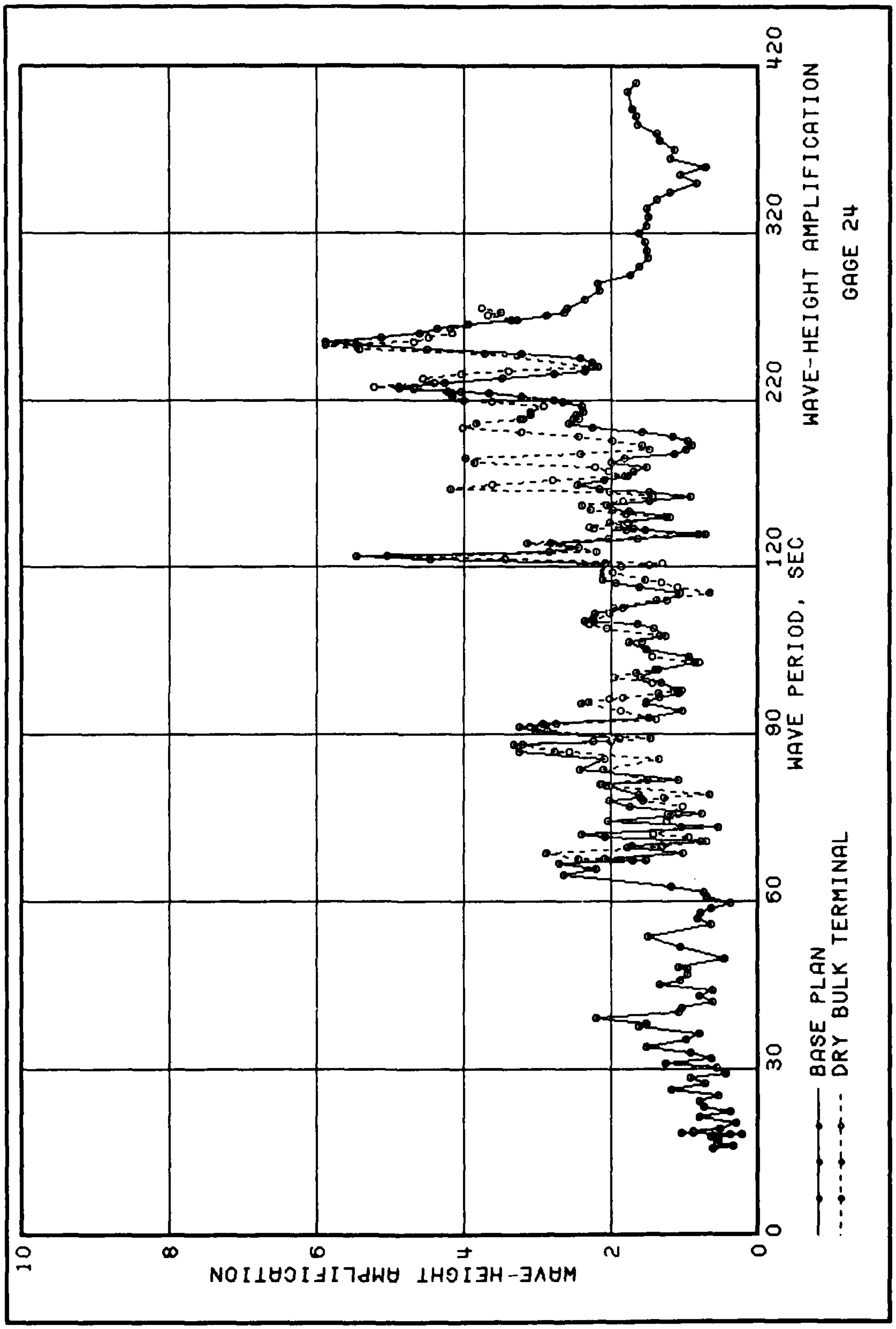
30
60
90
120
220
320
420
0
1
2
3
4
5

PLATE 25


WAVE-HEIGHT AMPLIFICATION
GAGE 24
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
BASE PLAN
DRY BULK TERMINAL
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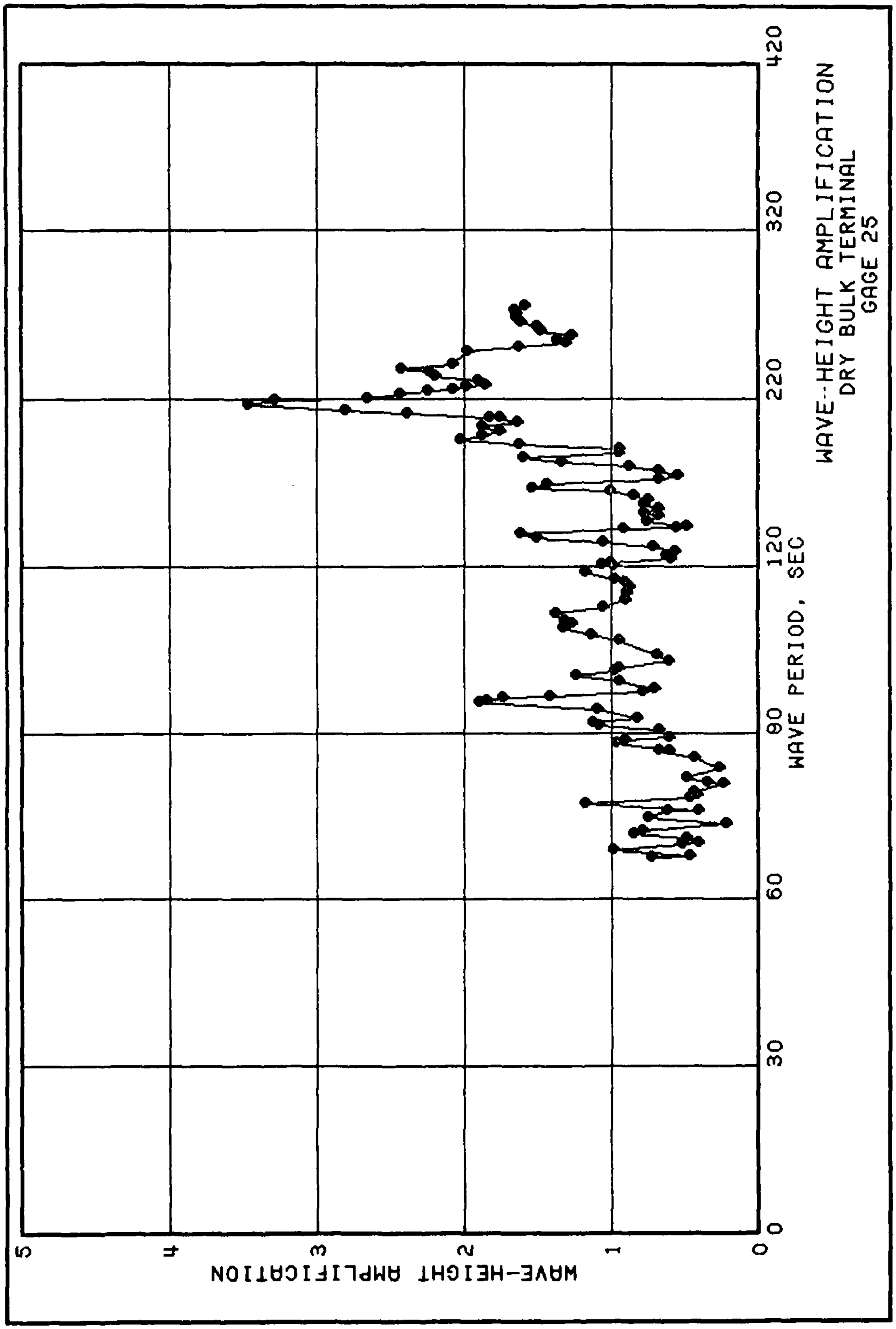
30
60
90
120
220
320
420
0
2
4
6
8
10

PLATE 26


WAVE-HEIGHT AMPLIFICATION
DRY BULK TERMINAL
GAGE 25
WAVE PERIOD, SEC
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60
90
120
220
320
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WAVE-HEIGHT AMPLIFICATION
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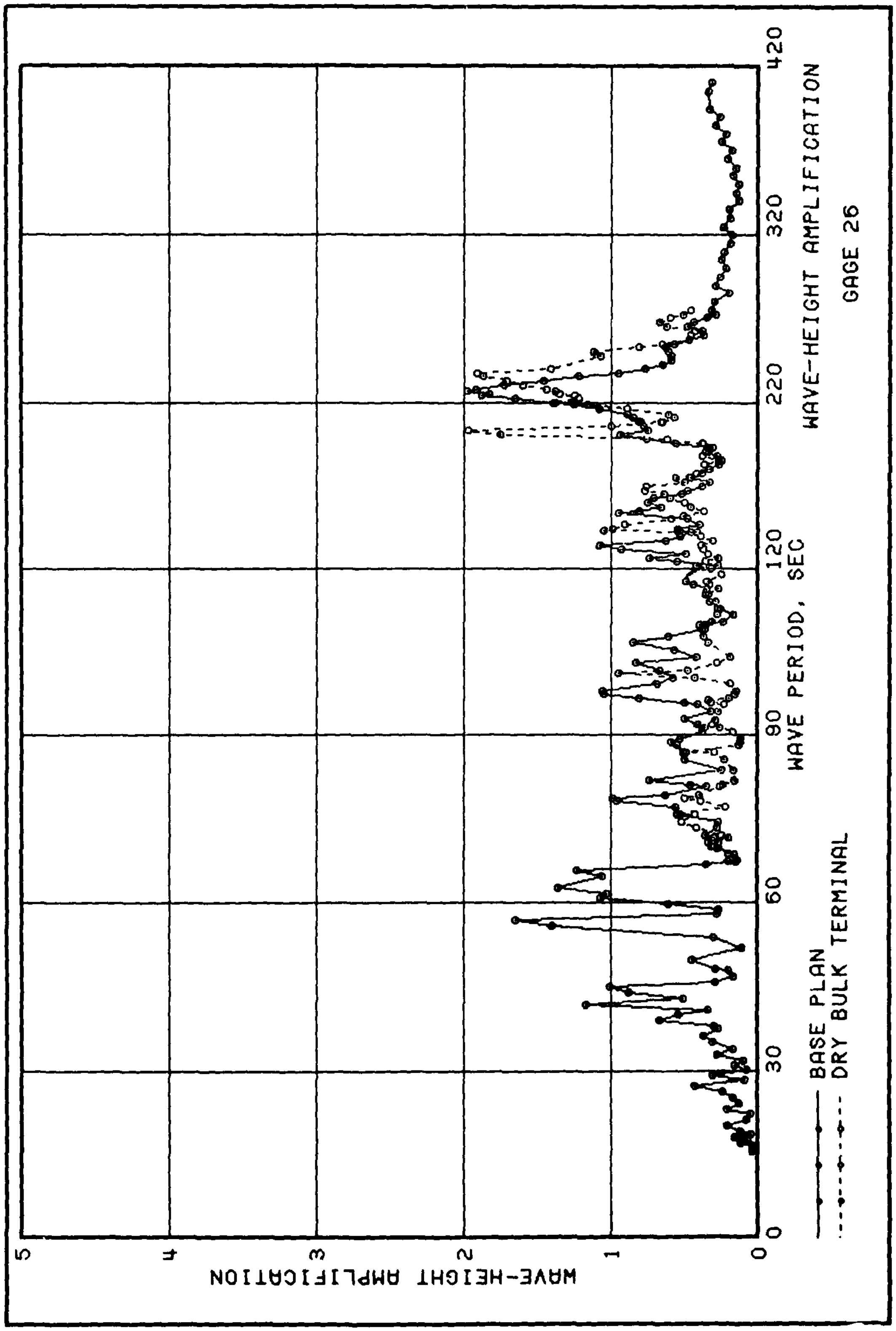
1
2
3
4
5


WAVE-HEIGHT AMPLIFICATION
GAGE 26
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
BASE PLAN
DRY BULK TERMINAL
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420
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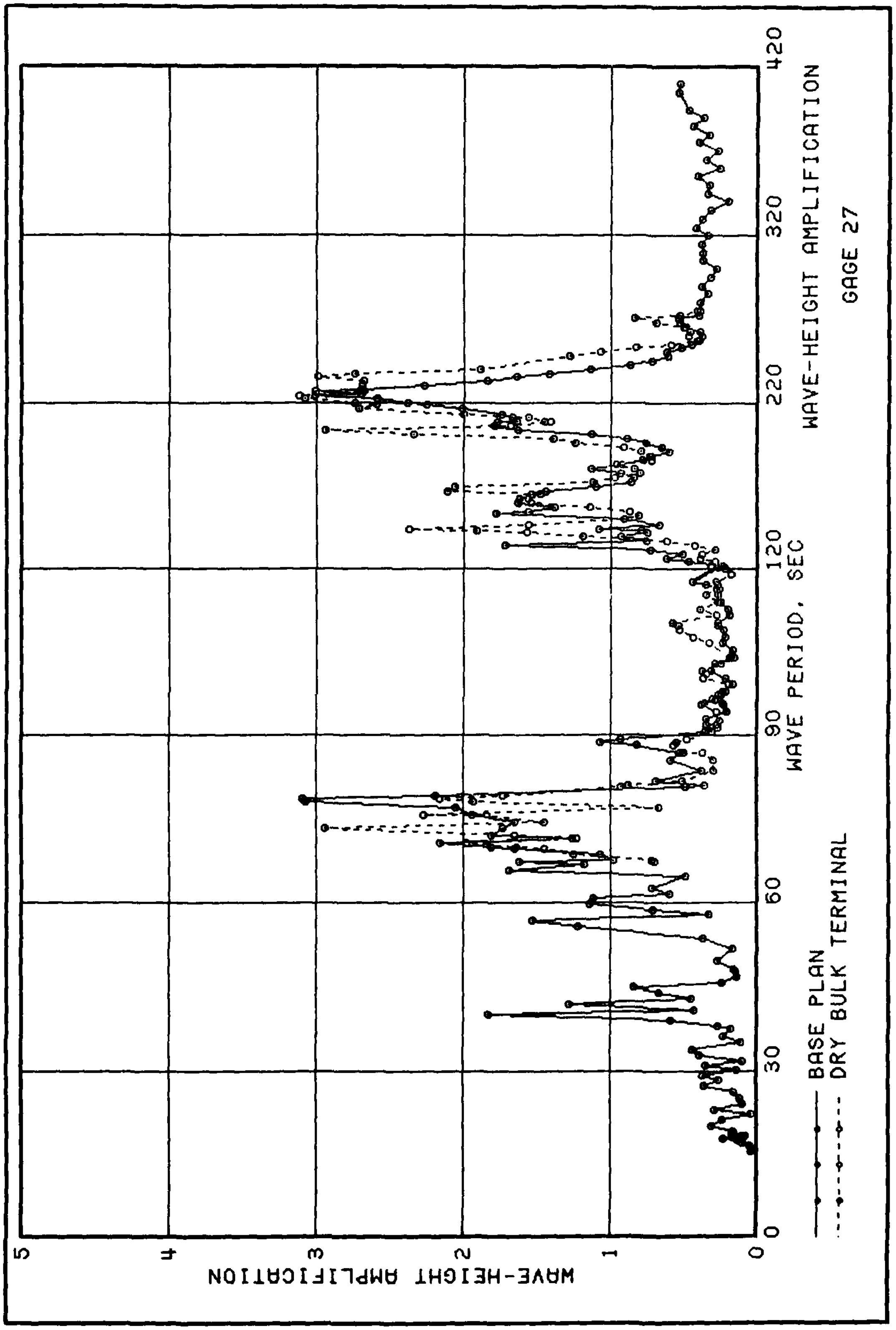
1
2
3
4
5

PLATE 28


WAVE-HEIGHT AMPLIFICATION
GAGE 27
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
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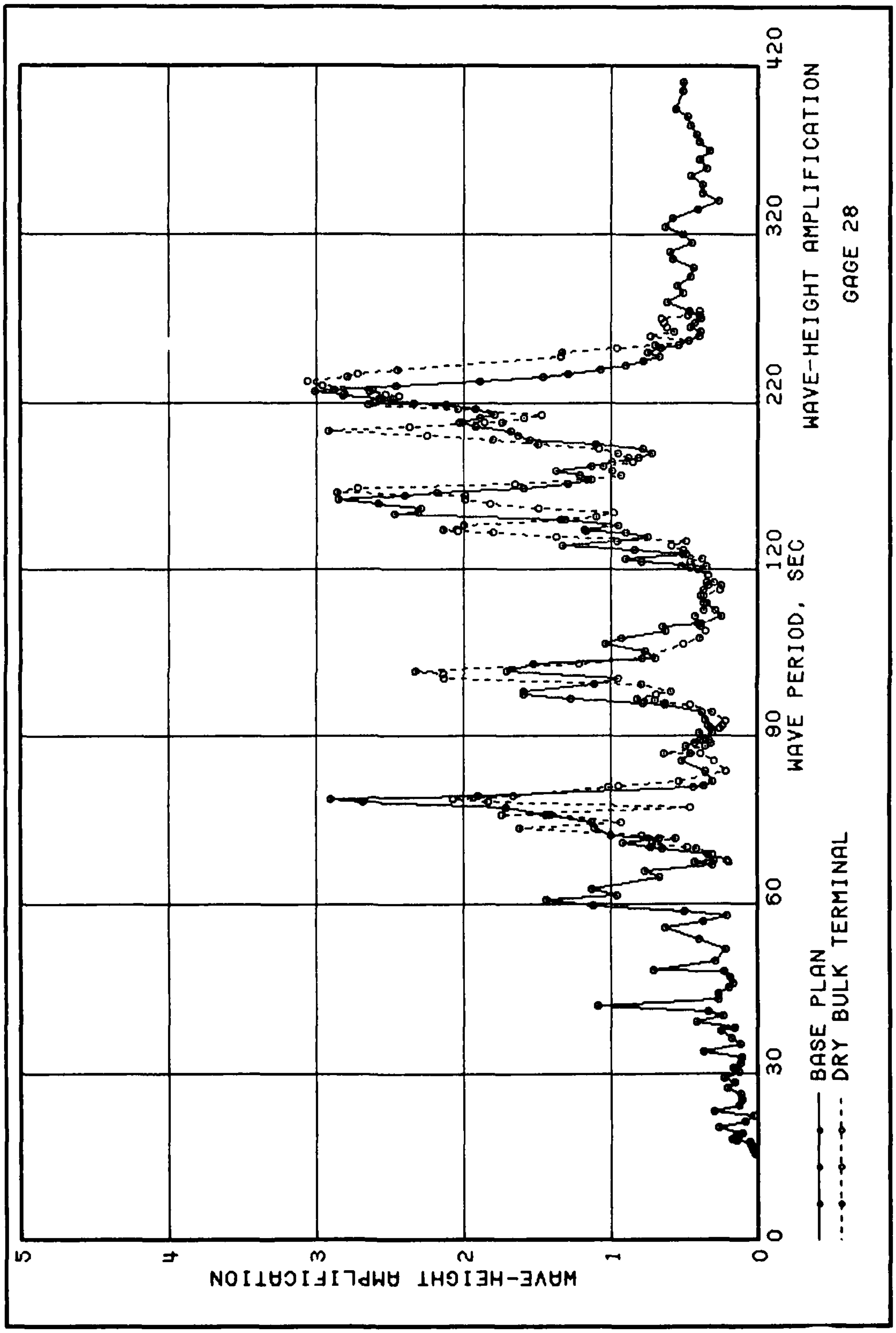
420
0
1
2
3
4
5
BASE PLAN
DRY BULK TERMINAL


WAVE-HEIGHT AMPLIFICATION
GAGE 28
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
BASE PLAN
DRY BULK TERMINAL
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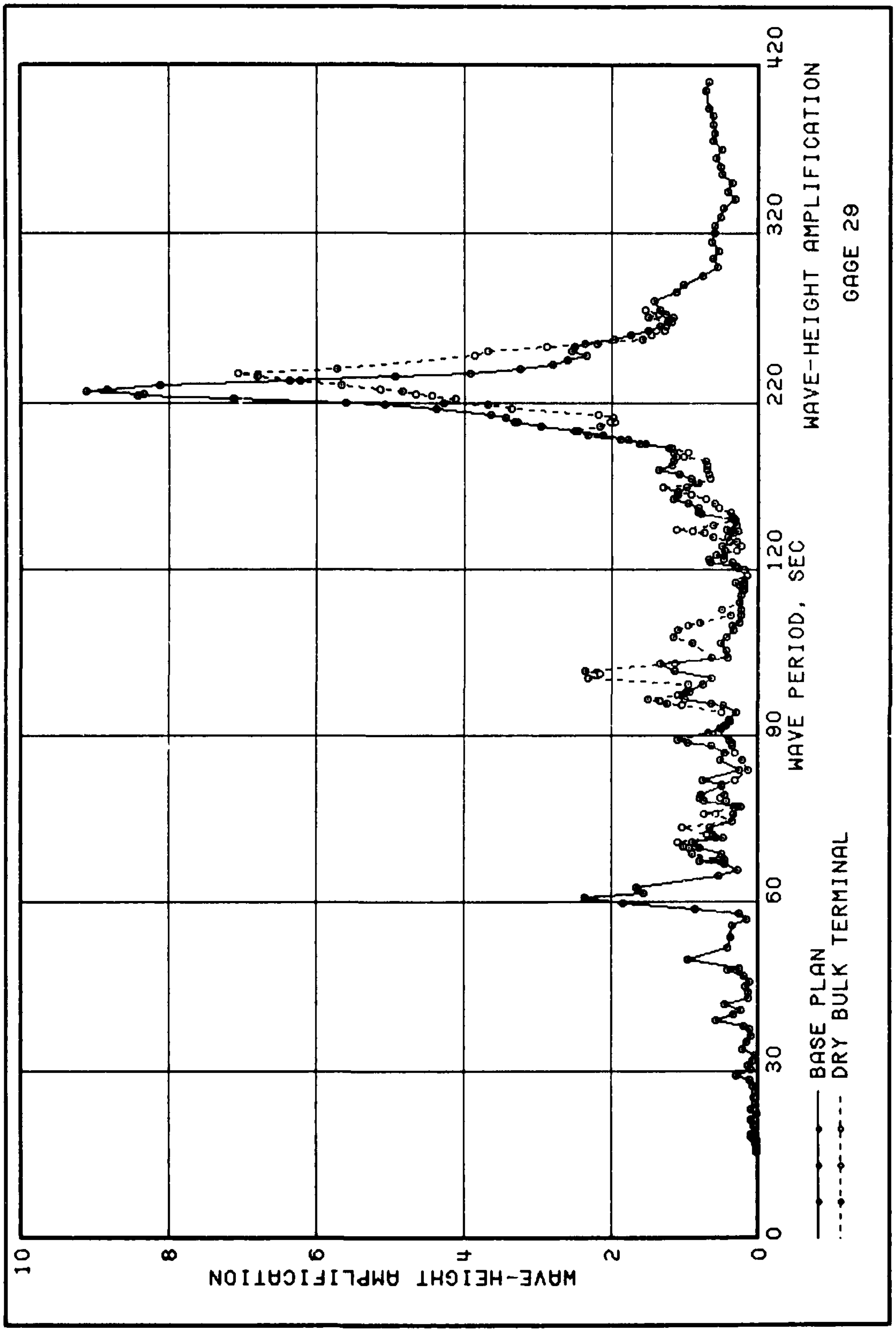
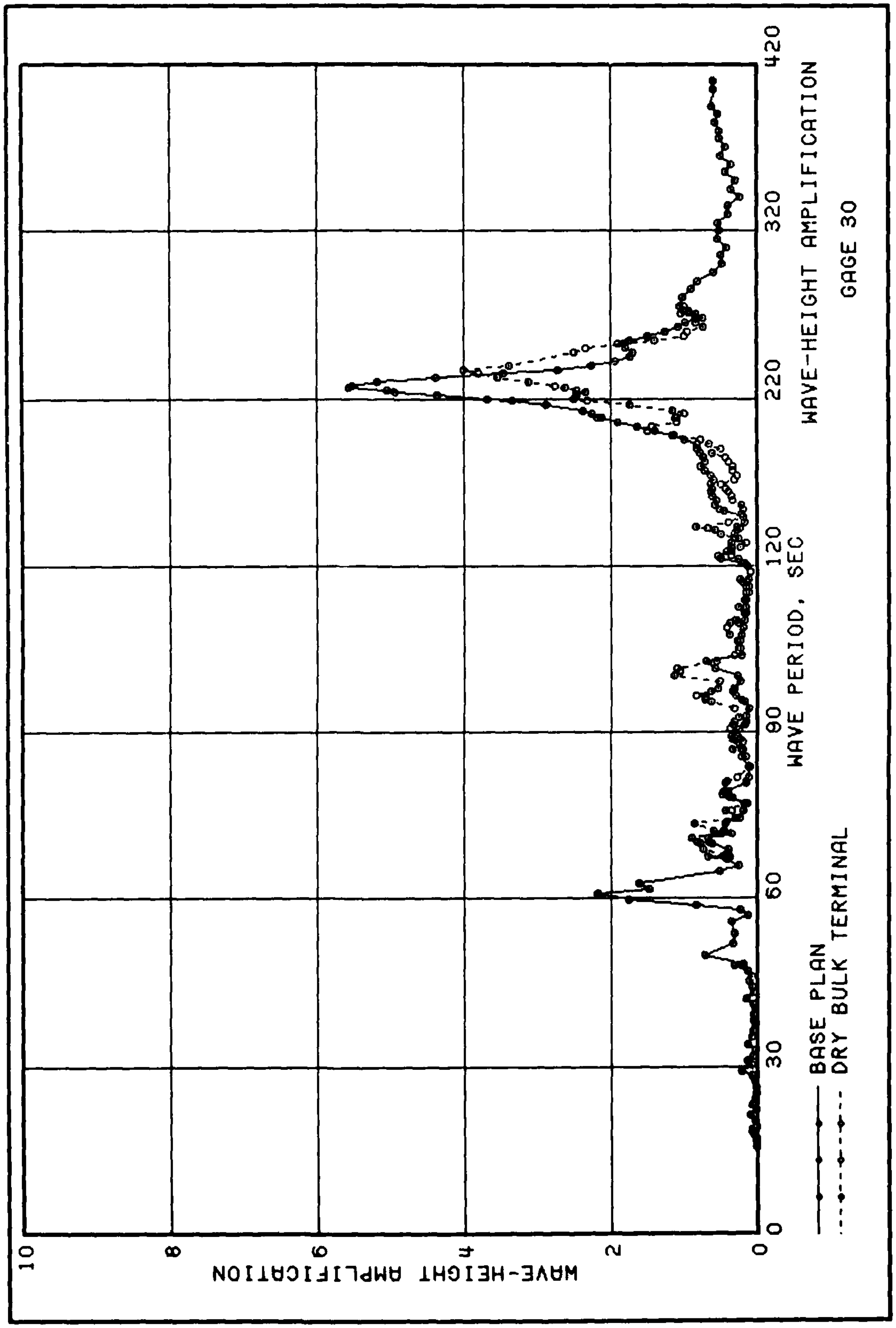
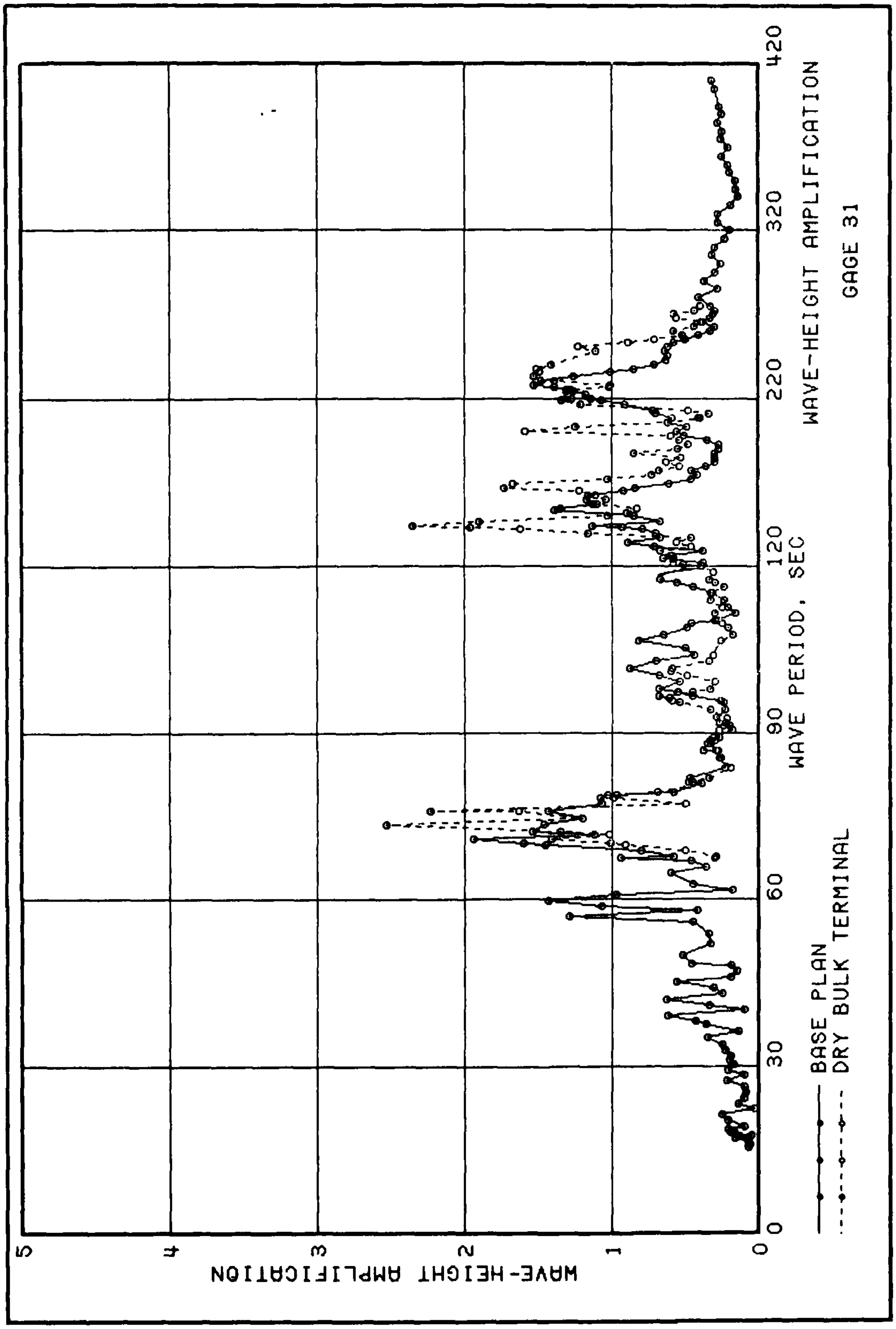
30
60
90
120
220
320
420
0
1
2
3
4
5

PLATE 30


WAVE-HEIGHT AMPLIFICATION
GAGE 29
WAVE-HEIGHT AMPLIFICATION
WAVE PERIOD, SEC
BASE PLAN
DRY BULK TERMINAL
0
2
4
6
8
10
0
30
60
90
120
220
320
420


WAVE-HEIGHT AMPLIFICATION
GAGE 30
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
BASE PLAN
DRY BULK TERMINAL
0
30
60
90
120
220
320
420
0
2
4
6
8
10



WAVE-HEIGHT AMPLIFICATION
GAGE 31
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
BASE PLAN
DRY BULK TERMINAL
0
30
60
90
120
220
320
420
0
1
2
3
4
5

PLATE 33

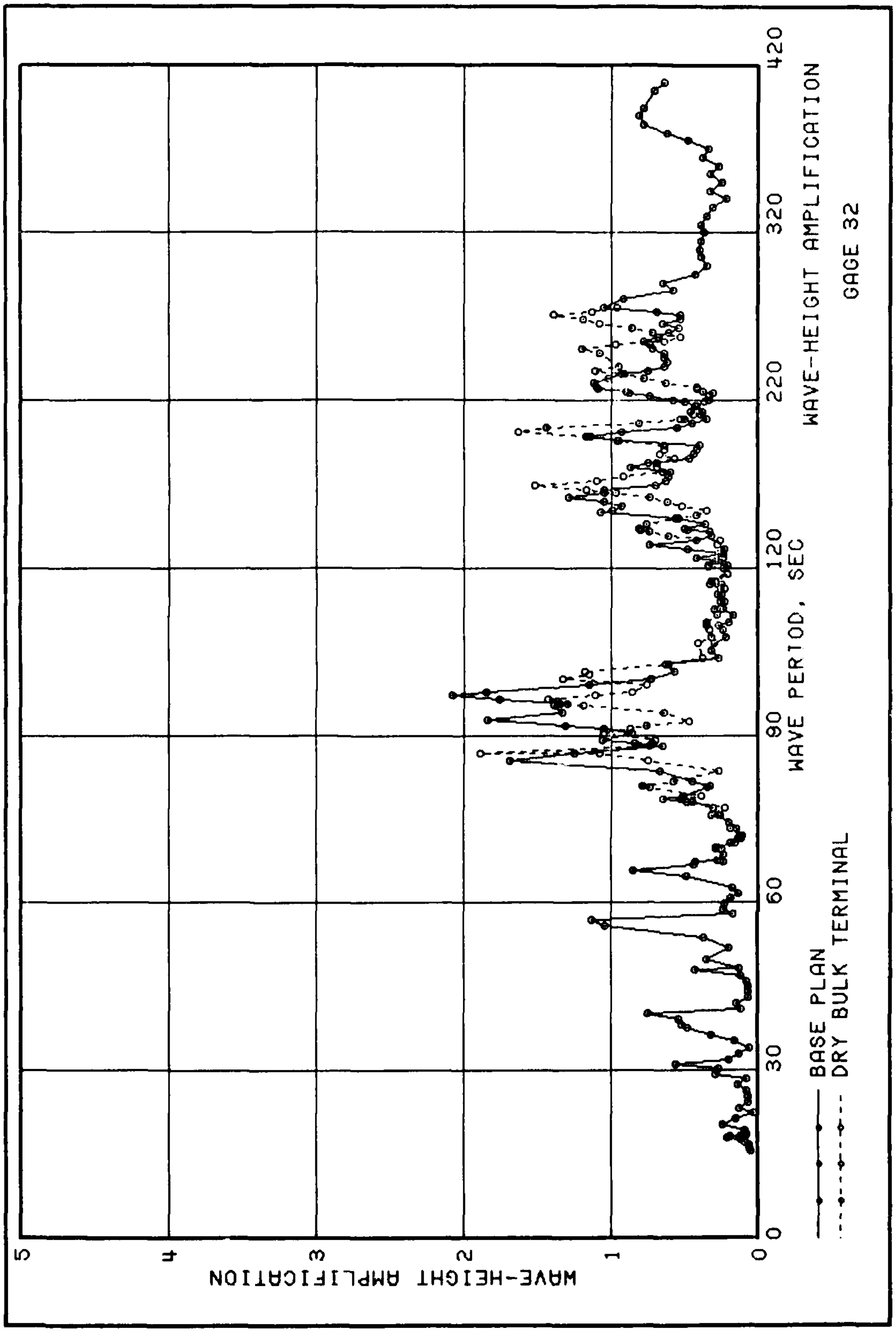

WAVE-HEIGHT AMPLIFICATION
GAGE 32
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
BASE PLAN
DRY BULK TERMINAL
0
30
60
90
120
220
320
420
0
1
2
3
4
5

PLATE 34

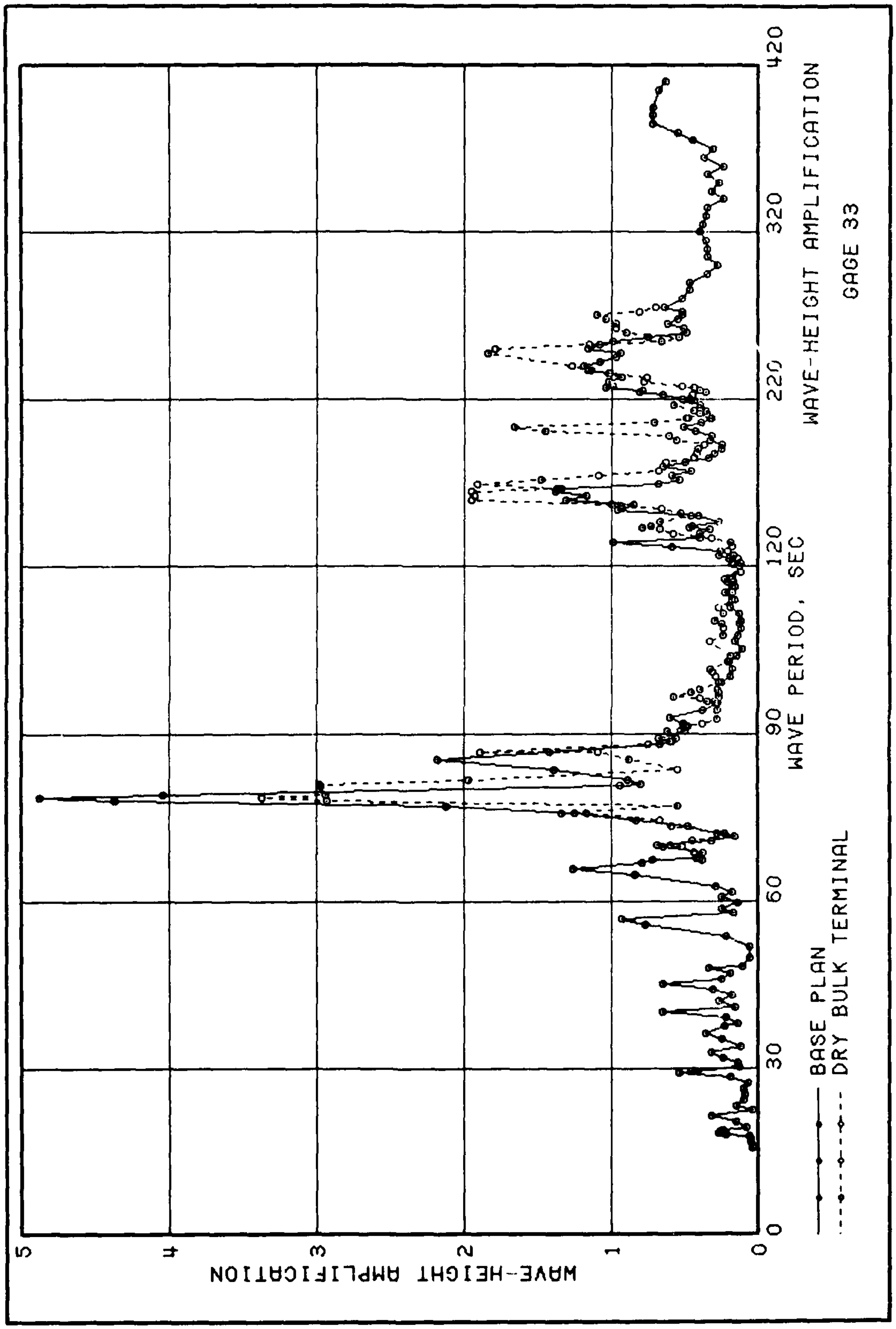
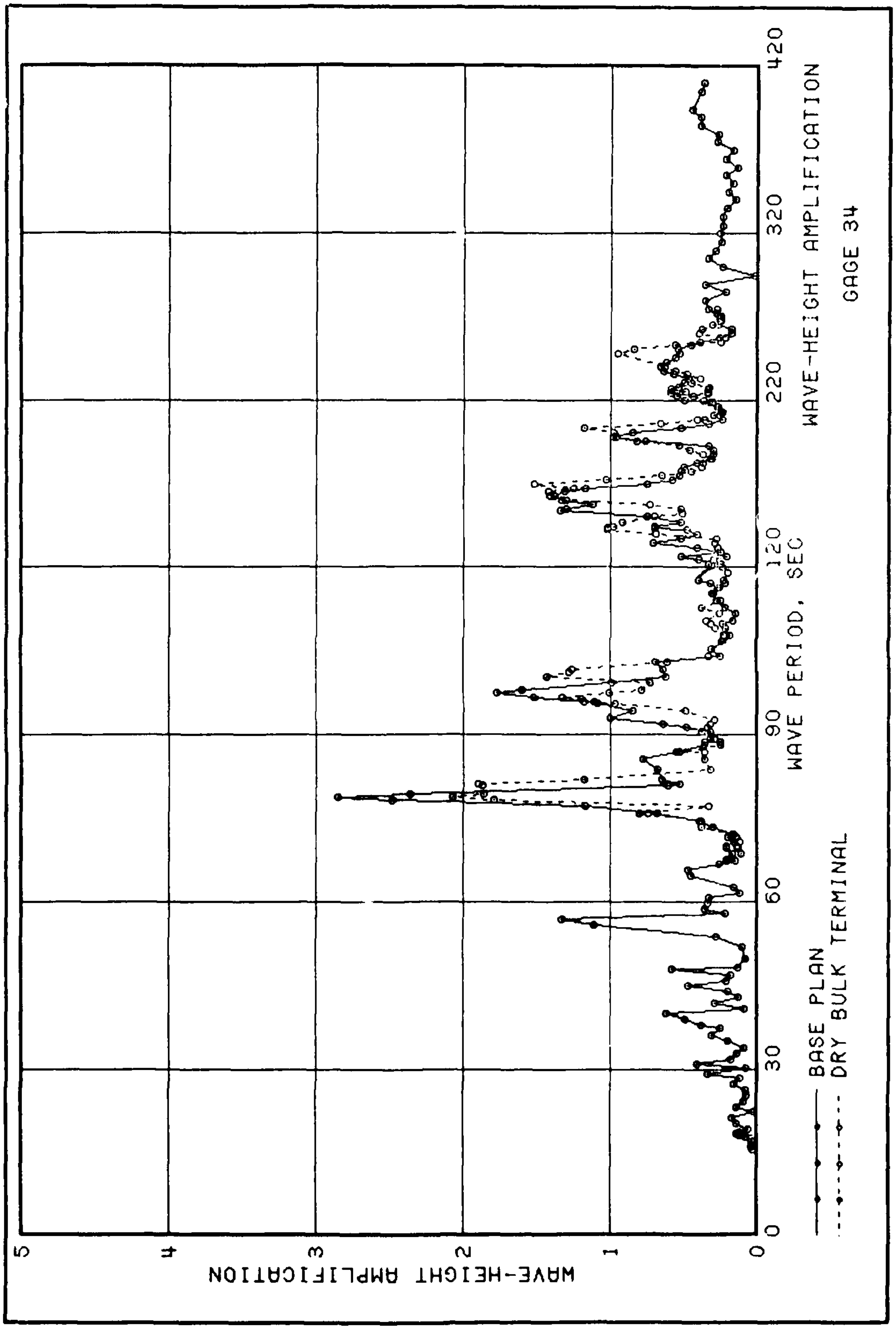
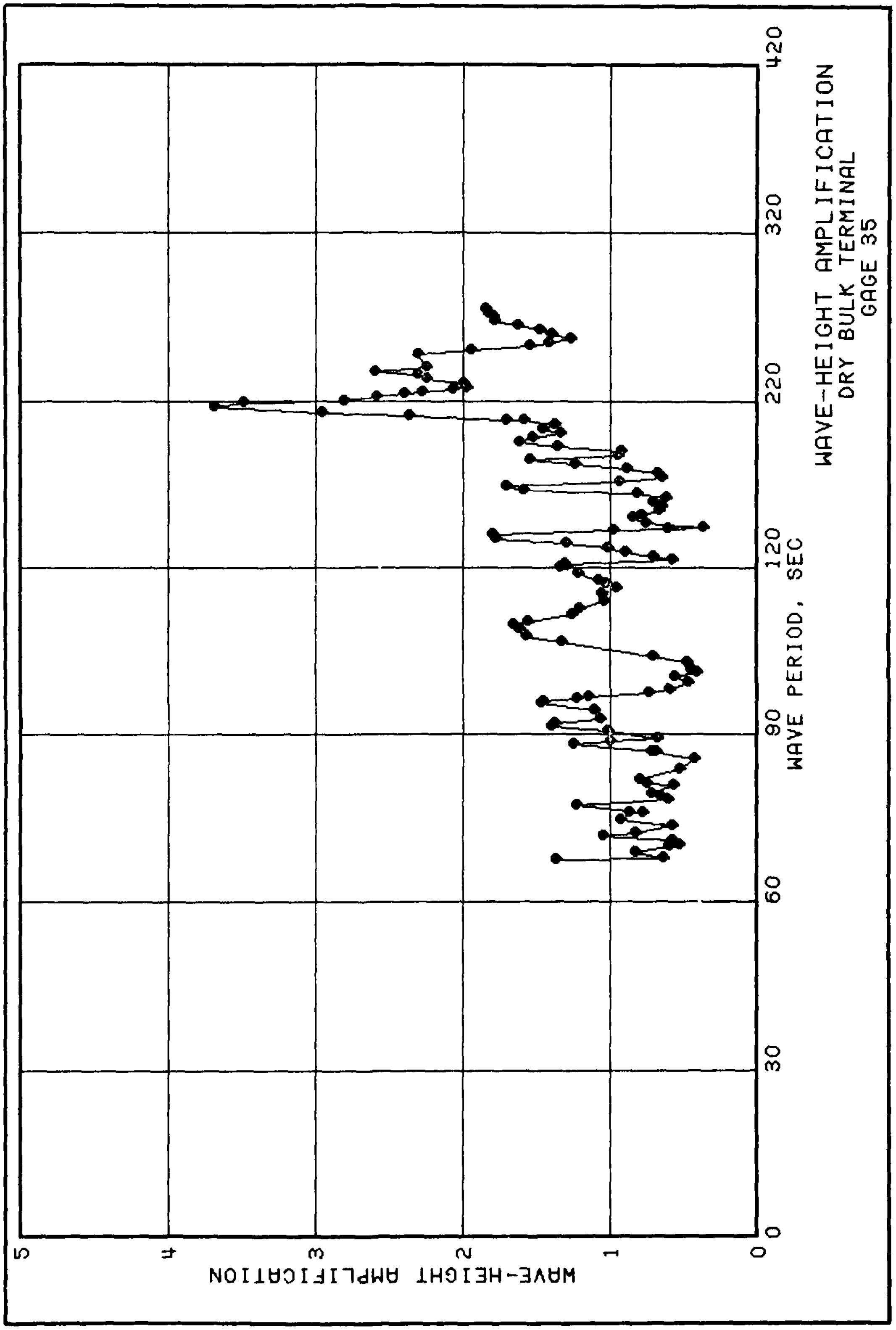

WAVE-HEIGHT AMPLIFICATION
GAGE 33
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
0
30
60
90
120
220
320
420
0
1
2
3
4
5
BASE PLAN
DRY BULK TERMINAL

PLATE 35



WAVE-HEIGHT AMPLIFICATION
GAGE 34
WAVE-HEIGHT AMPLIFICATION
WAVE PERIOD, SEC
BASE PLAN
DRY BULK TERMINAL
0
1
2
3
4
5
0
30
60
90
120
220
320
420

PLATE 36


WAVE-HEIGHT AMPLIFICATION
DRY BULK TERMINAL
GAGE 35
WAVE PERIOD, SEC
0
30
60
90
120
220
320
420
WAVE-HEIGHT AMPLIFICATION
0
1
2
3
4
5

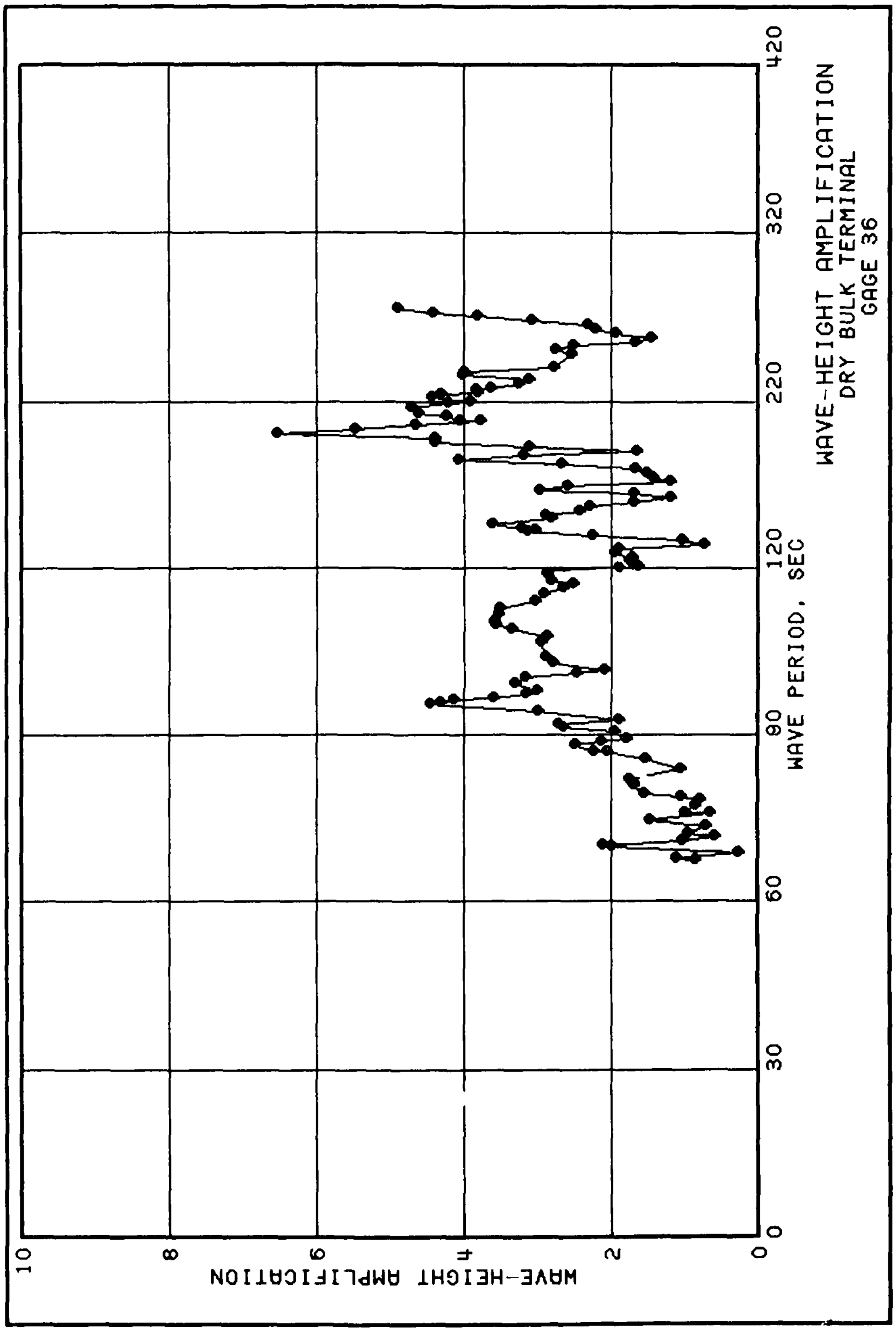

WAVE-HEIGHT AMPLIFICATION
DRY BULK TERMINAL
GAGE 36
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
0
30
60
90
120
220
320
420
0
2
4
6
8
10

PLATE 38

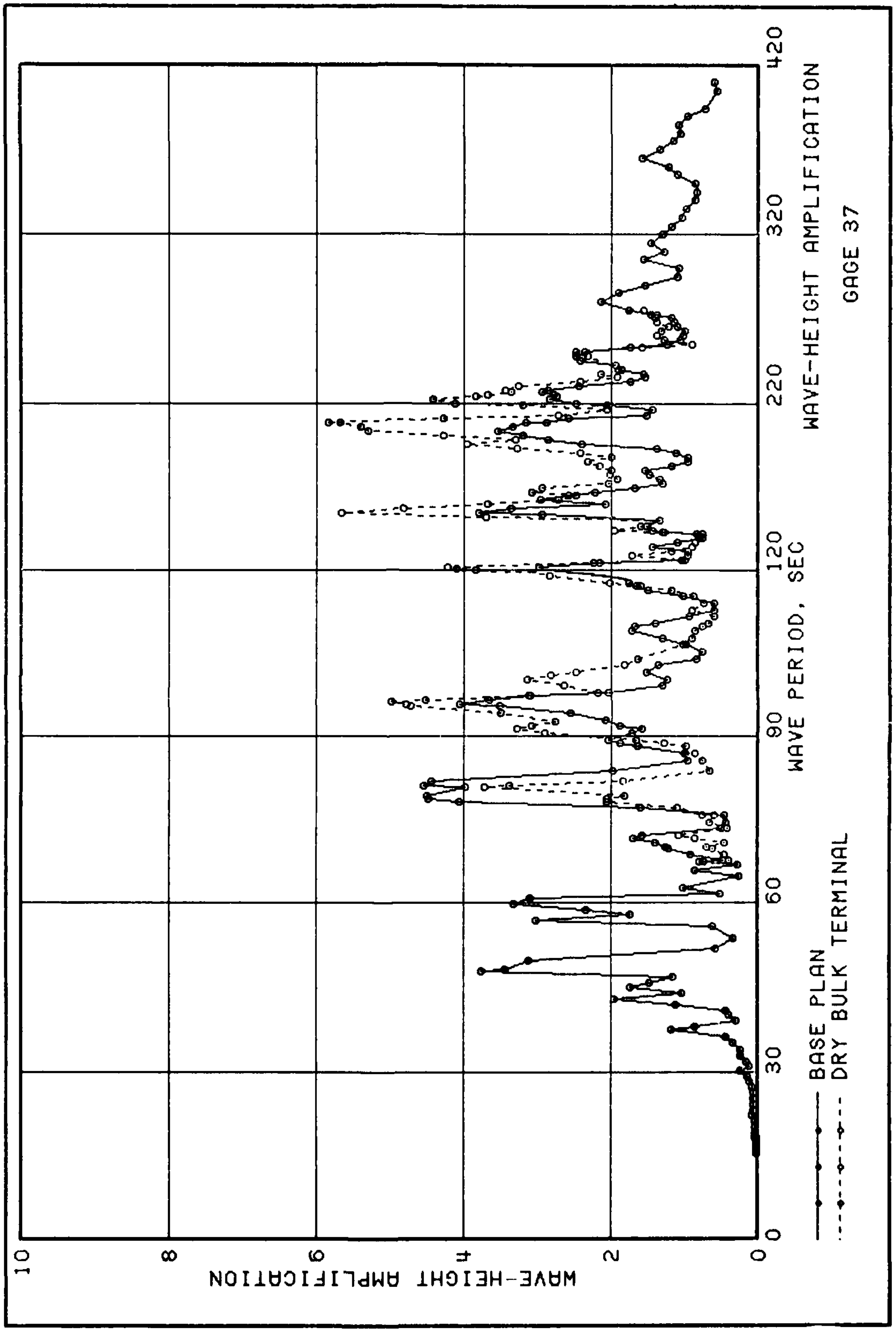

WAVE-HEIGHT AMPLIFICATION
GAGE 37
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
0
2
4
6
8
10
0
30
60
90
120
220
320
420
BASE PLAN
DRY BULK TERMINAL

PLATE 39

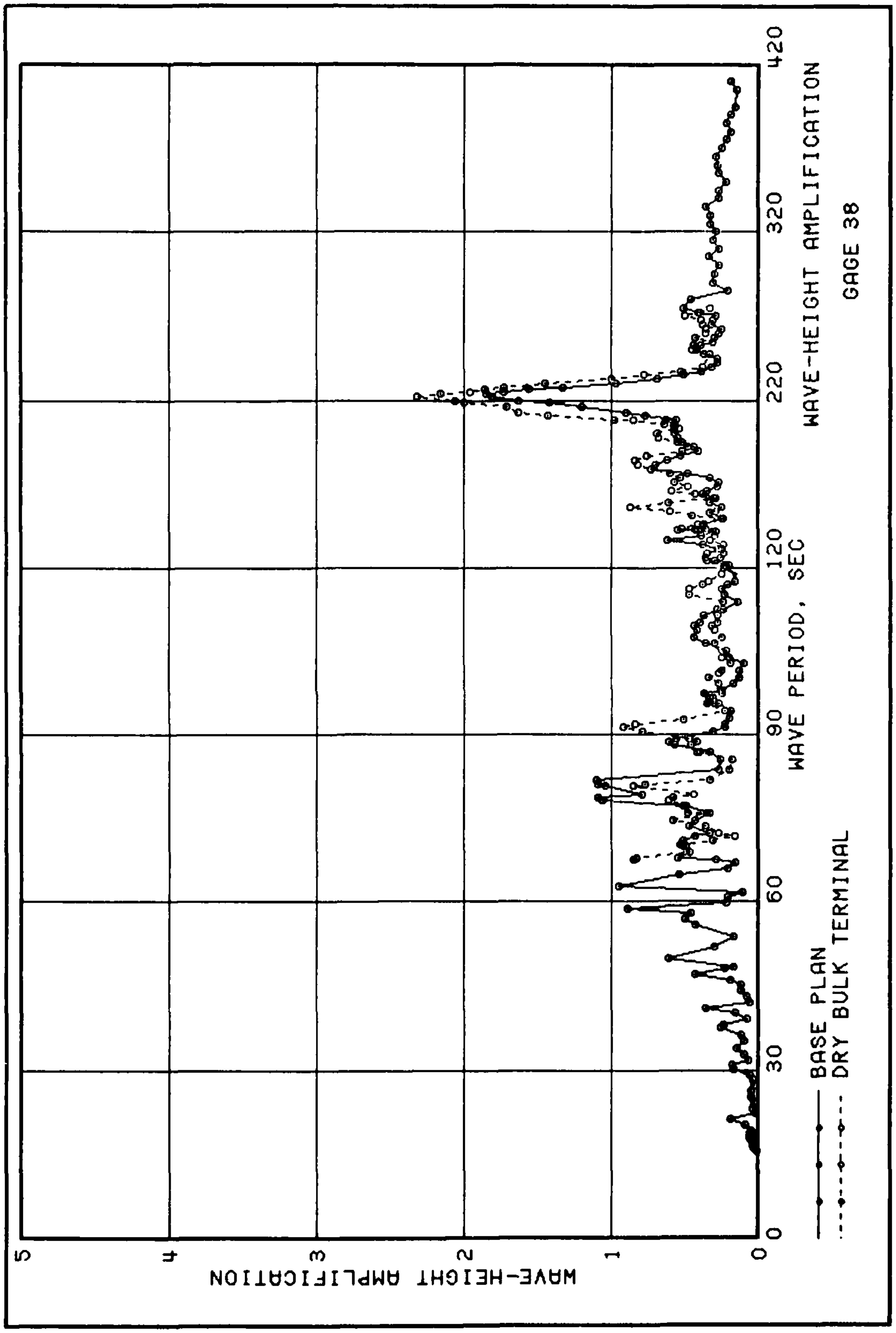
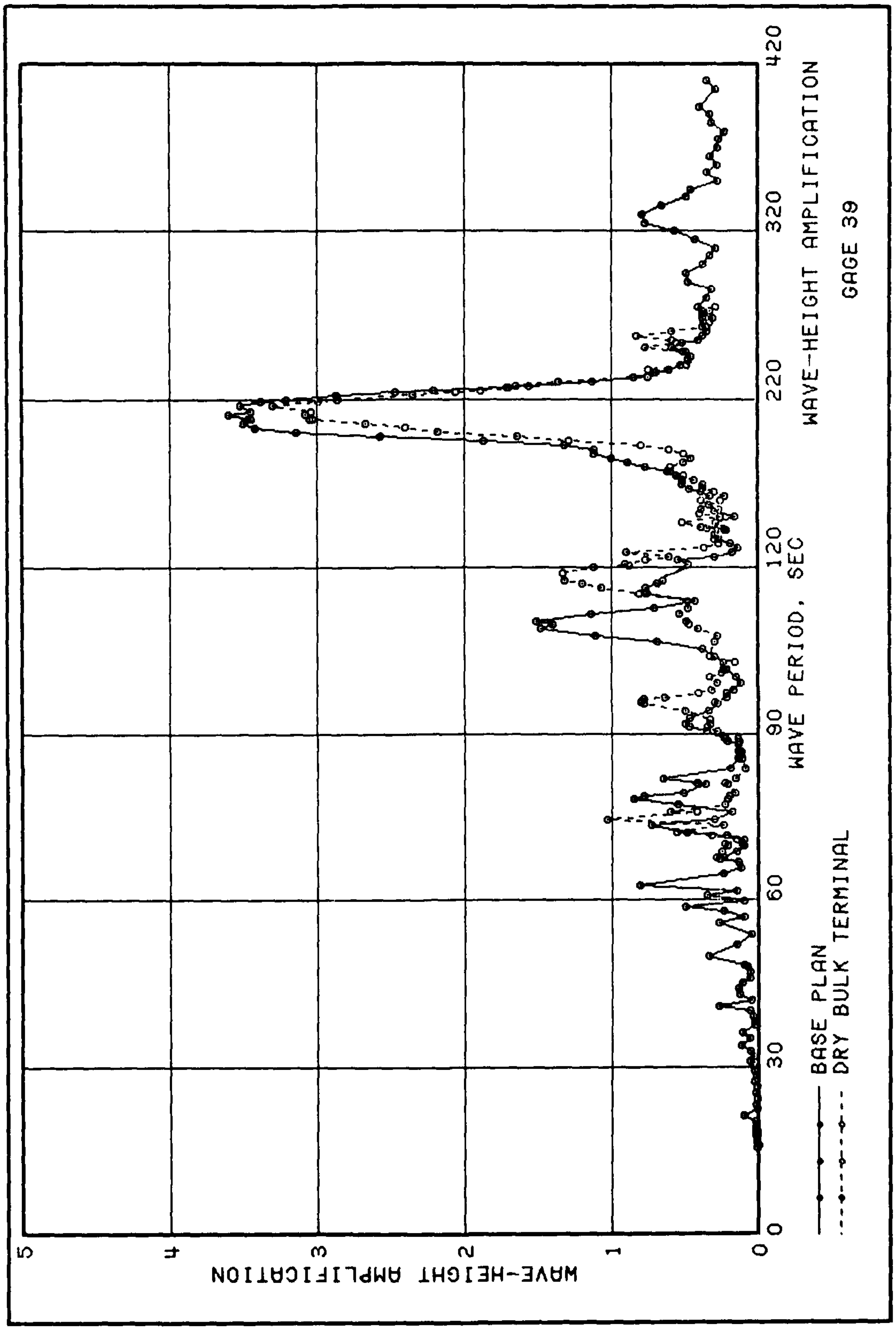
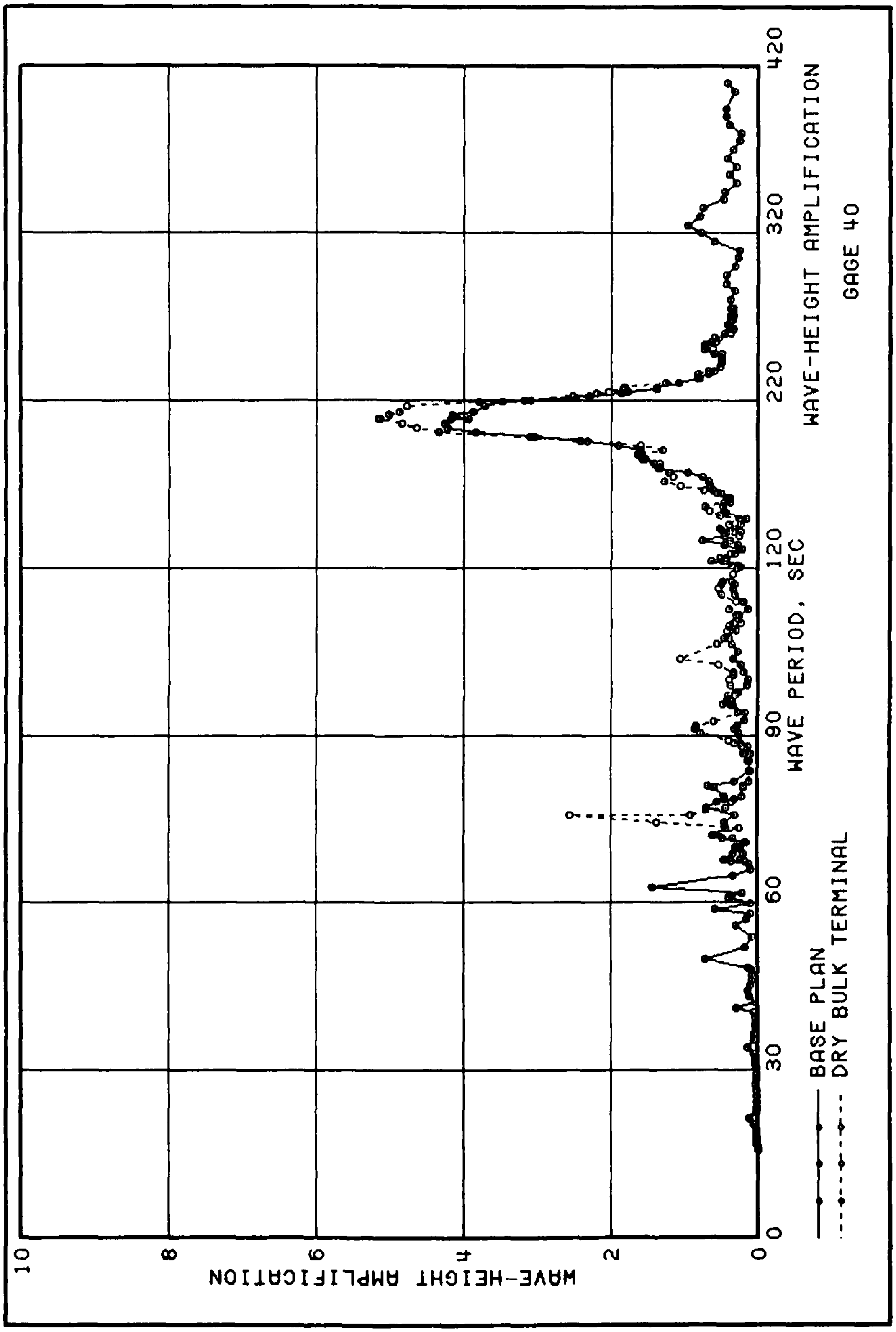

WAVE-HEIGHT AMPLIFICATION
GAGE 38
WAVE-HEIGHT AMPLIFICATION
WAVE PERIOD, SEC
0
1
2
3
4
5
0
30
60
90
120
220
320
420
BASE PLAN
DRY BULK TERMINAL

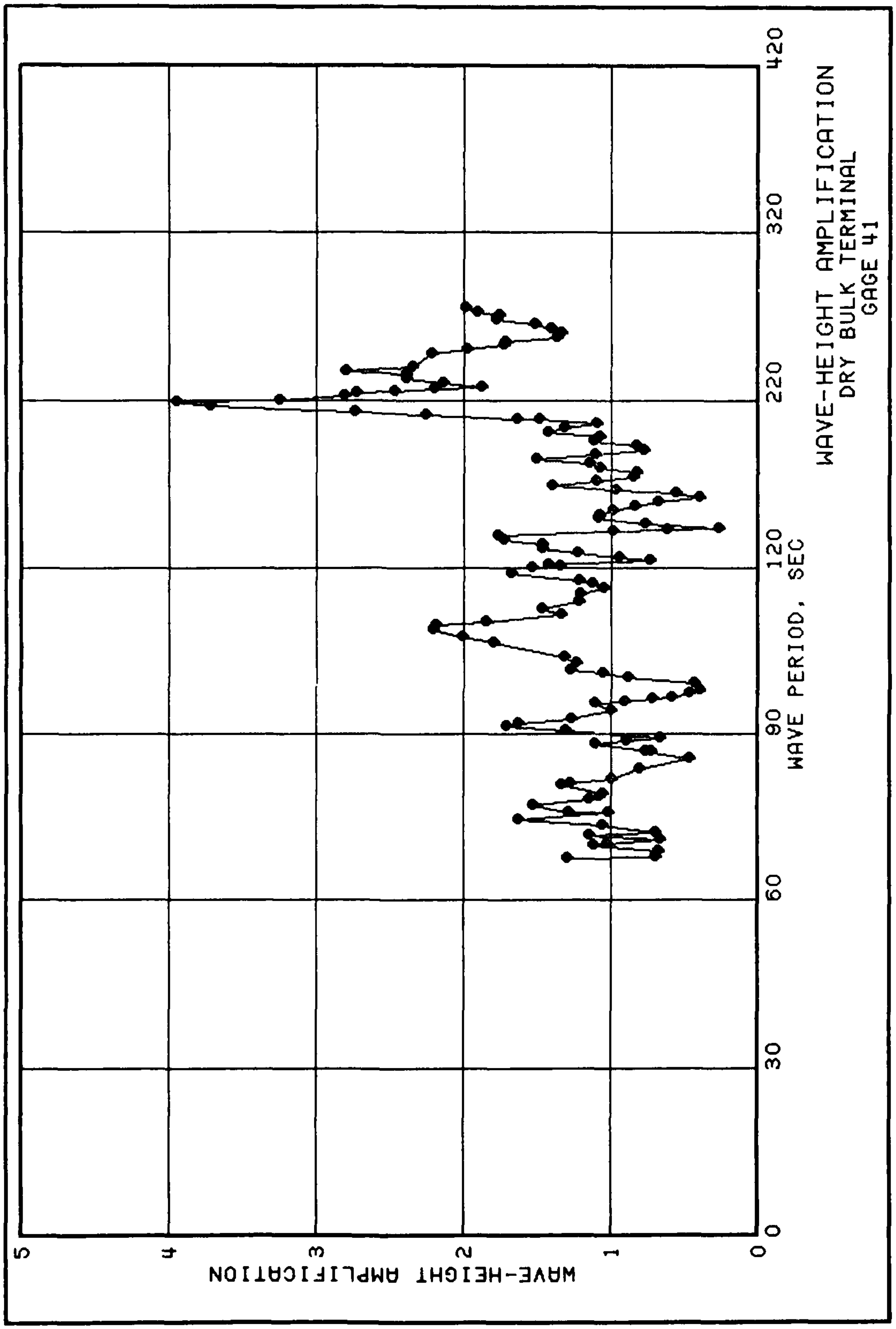
PLATE 40


WAVE-HEIGHT AMPLIFICATION
GAGE 39
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
BASE PLAN
DRY BULK TERMINAL
0
30
60
90
120
220
320
420
0
1
2
3
4
5



WAVE-HEIGHT AMPLIFICATION
GAGE 40
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
0
30
60
90
120
220
320
420
0
2
4
6
8
10
BASE PLAN
DRY BULK TERMINAL

PLATE 42


WAVE-HEIGHT AMPLIFICATION
DRY BULK TERMINAL
GAGE 41
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
0
30
60
90
120
220
320
420
0
1
2
3
4
5

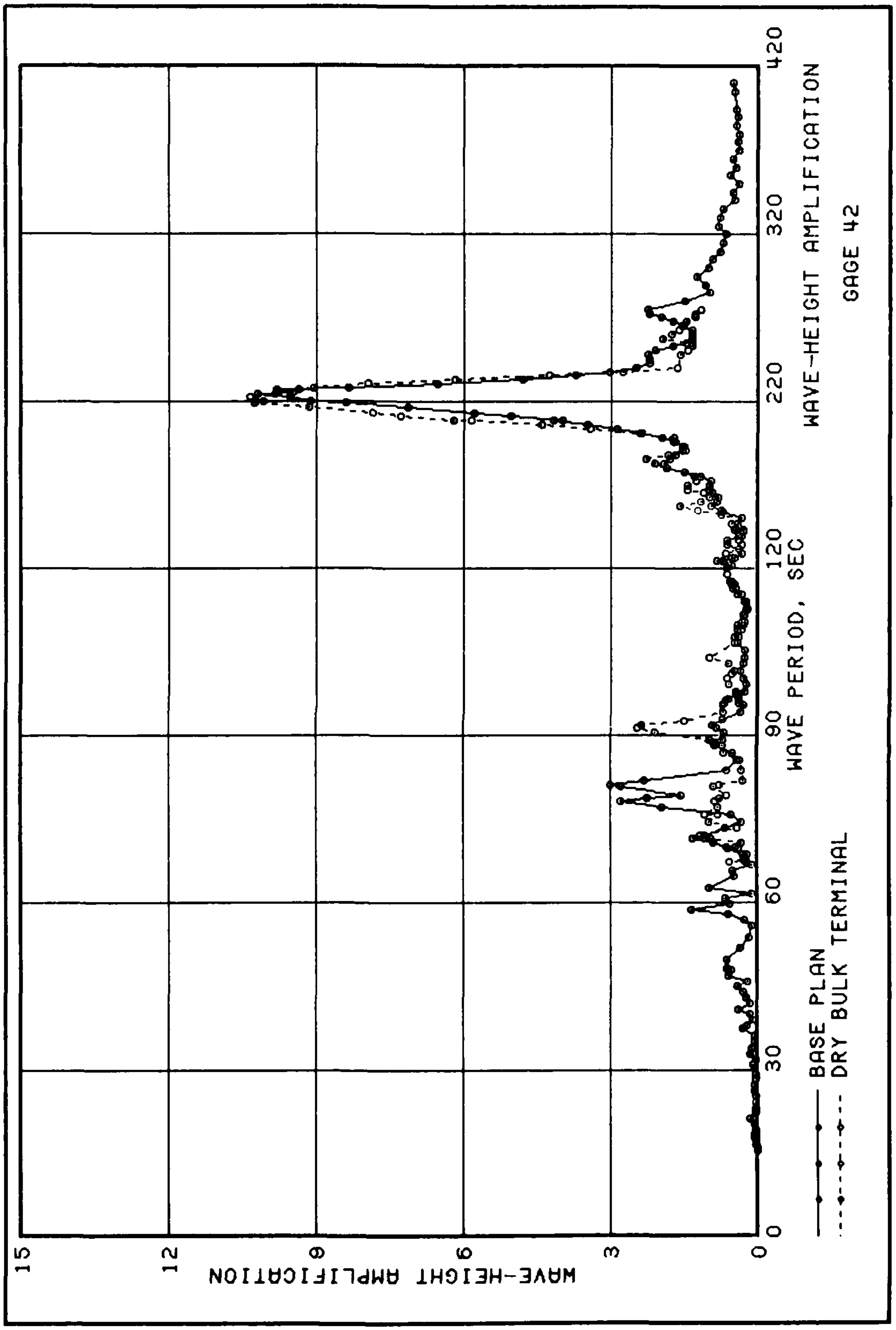
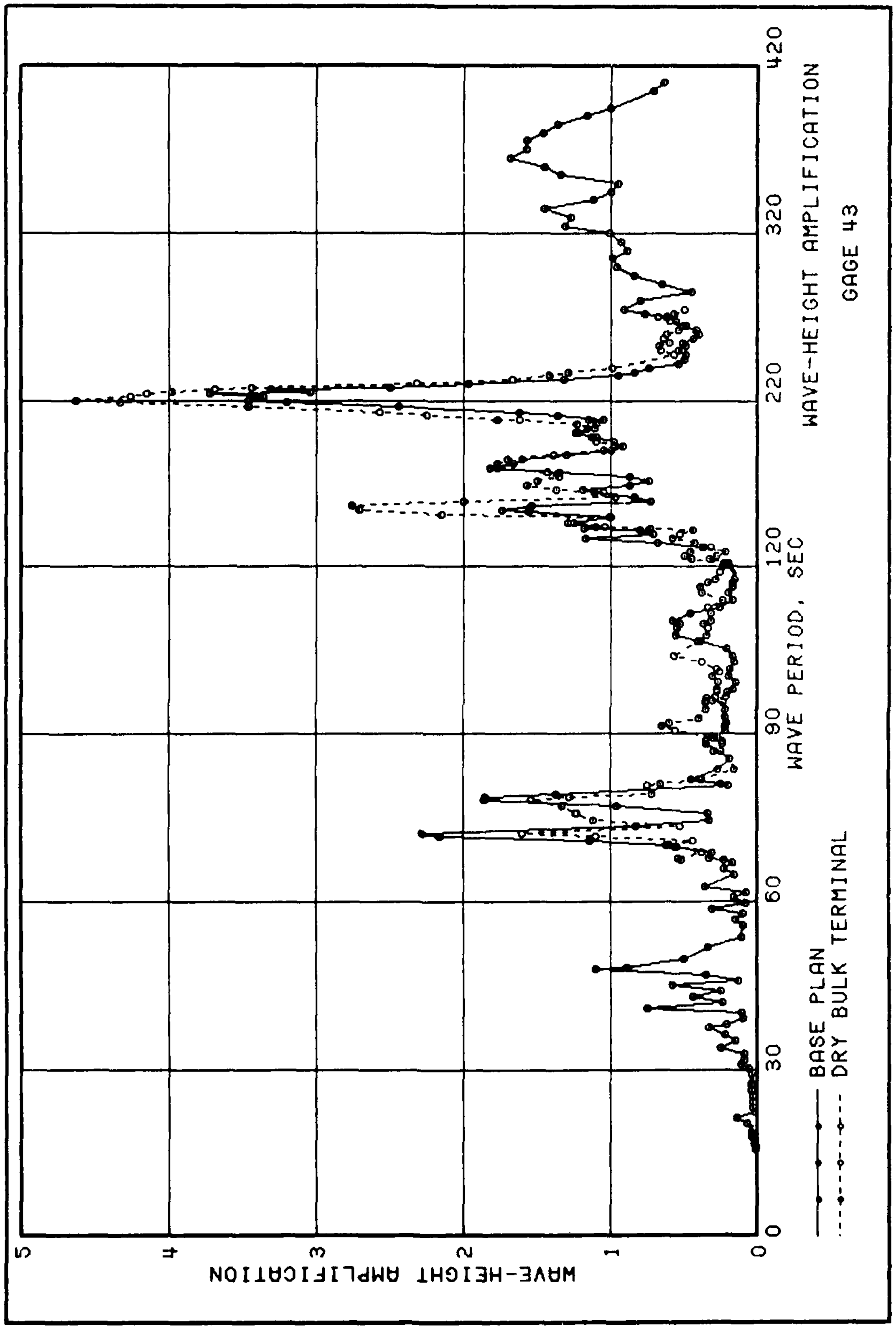

WAVE-HEIGHT AMPLIFICATION
GAGE 42
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
BASE PLAN
DRY BULK TERMINAL
0
30
60
90
120
220
320
420
0
3
6
9
12
15

PLATE 44



WAVE-HEIGHT AMPLIFICATION
GAGE 43
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
BASE PLAN
DRY BULK TERMINAL
0
30
60
90
120
220
320
420
0
1
2
3
4
5

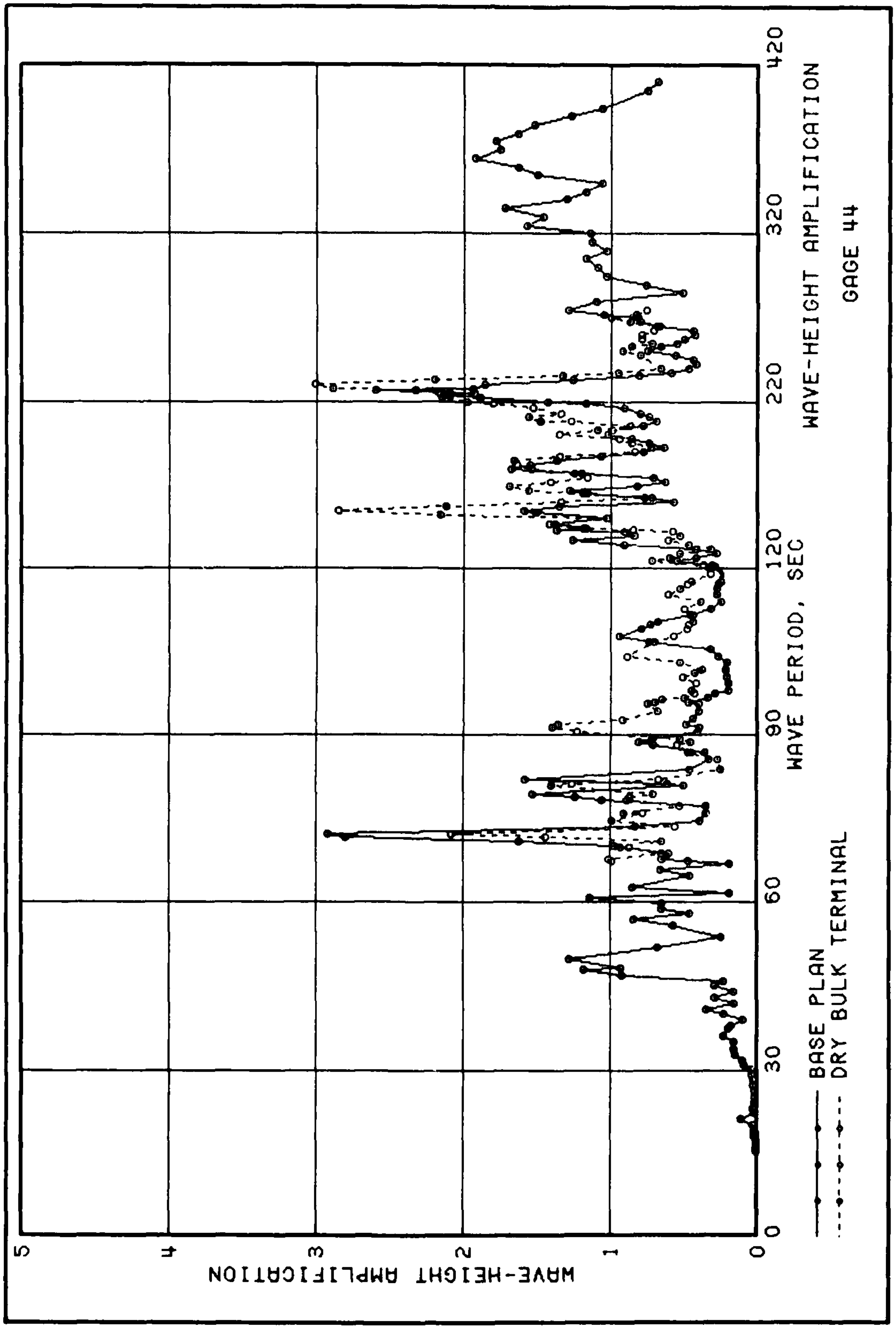
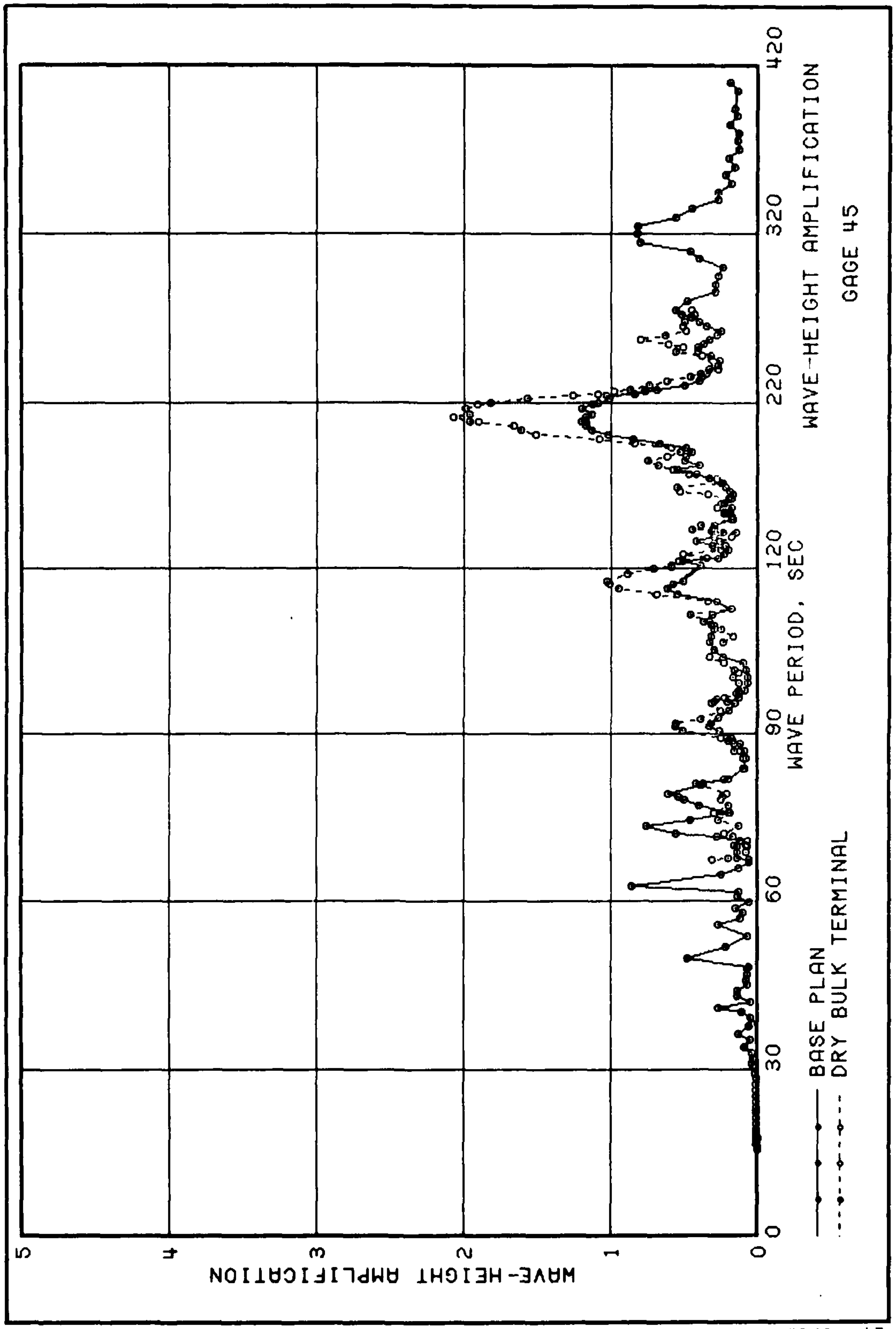
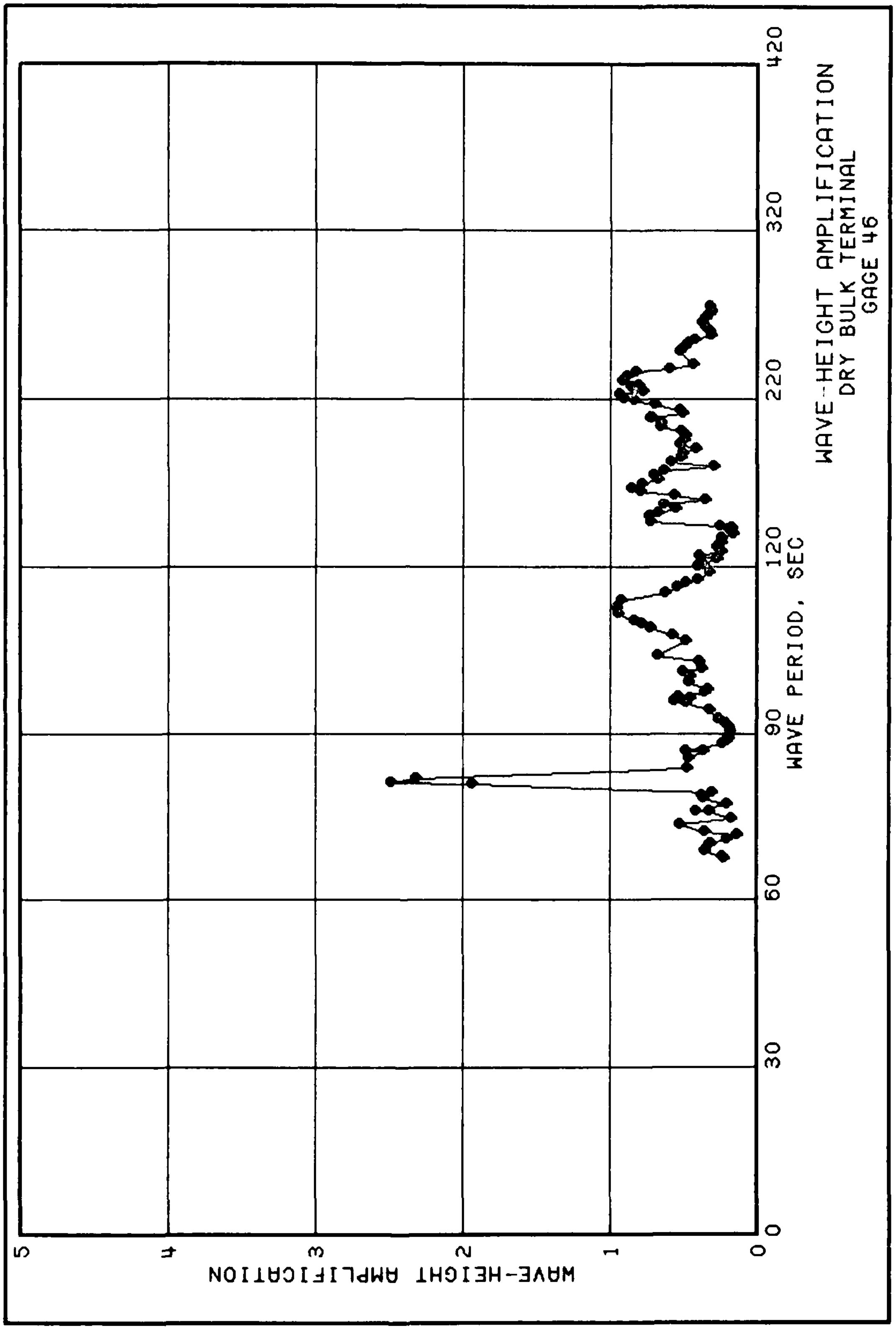
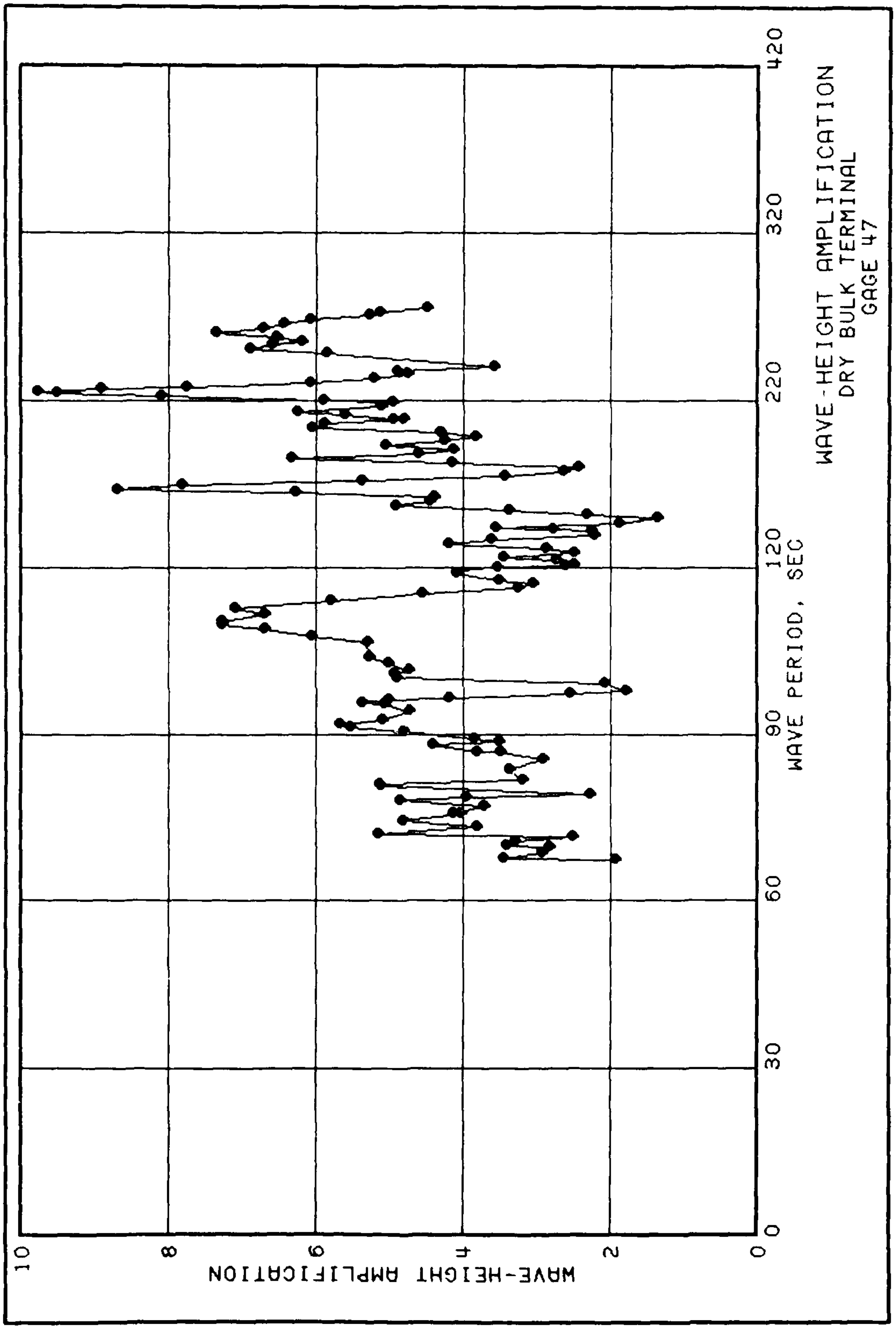

WAVE-HEIGHT AMPLIFICATION
GAGE 44
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
0
1
2
3
4
5
0
30
60
90
120
220
320
420
BASE PLAN
DRY BULK TERMINAL

PLATE 46


WAVE-HEIGHT AMPLIFICATION
GAGE 45
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
BASE PLAN
DRY BULK TERMINAL
0
30
60
90
120
220
320
420
0
1
2
3
4
5


WAVE-HEIGHT AMPLIFICATION
DRY BULK TERMINAL
GAGE 46
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
0
30
60
90
120
220
320
420
0
1
2
3
4
5


WAVE-HEIGHT AMPLIFICATION
DRY BULK TERMINAL
GAGE 47
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
0
30
60
90
120
220
320
420
0
2
4
6
8
10

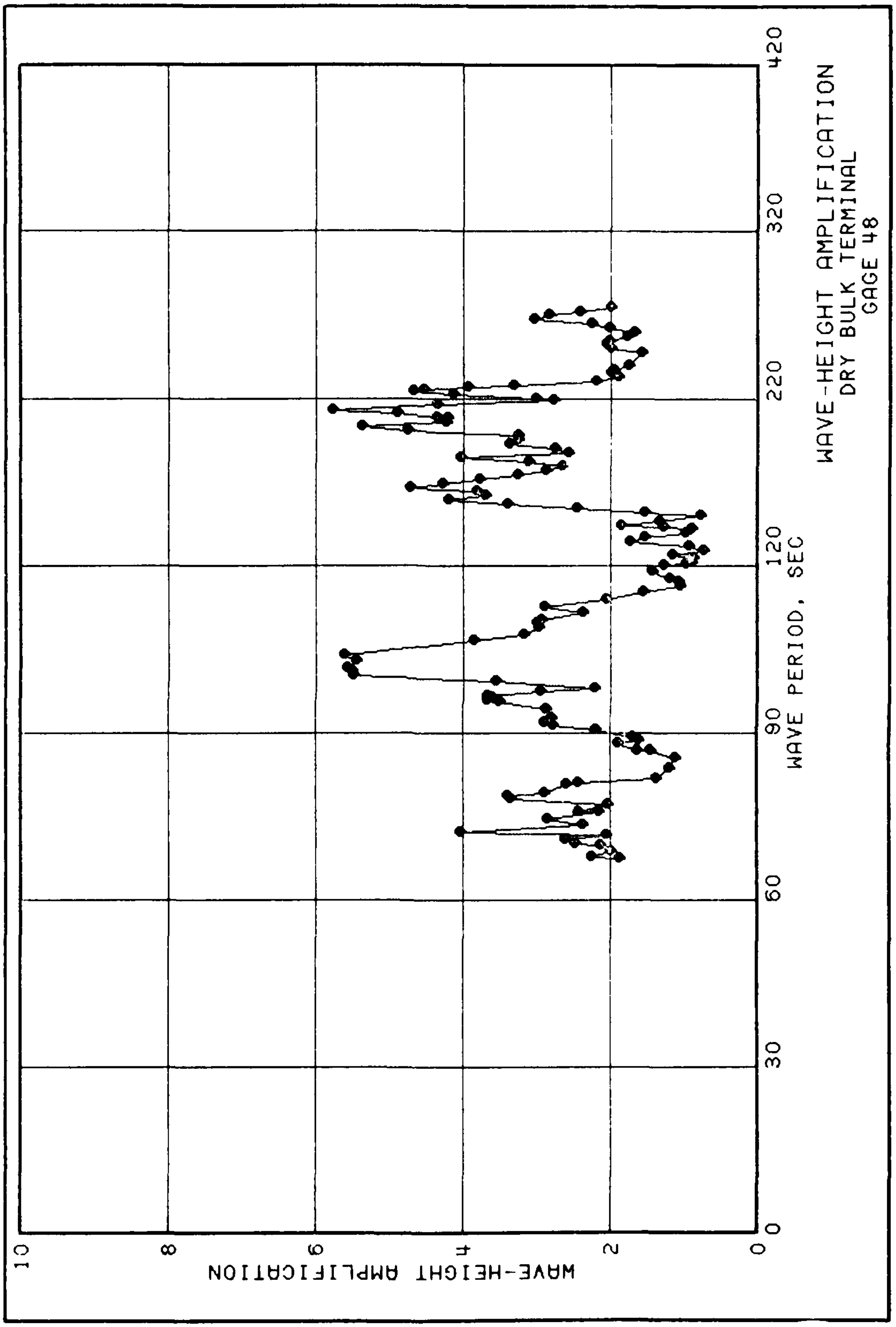
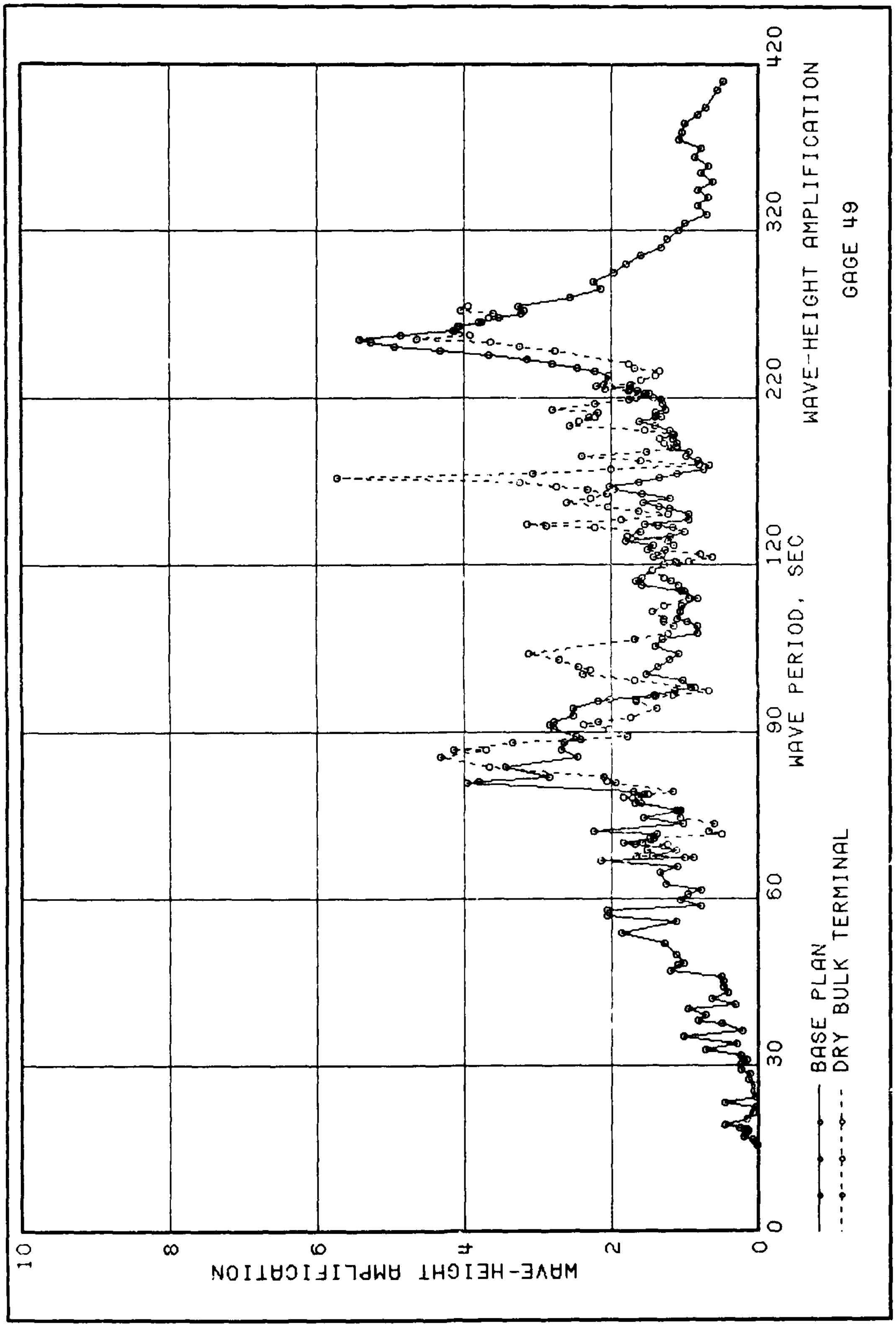

WAVE-HEIGHT AMPLIFICATION
DRY BULK TERMINAL
GAGE 48
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
0
30
60
90
120
220
320
420
0
2
4
6
8
10

PLATE 50



WAVE-HEIGHT AMPLIFICATION
GAGE 49
WAVE PERIOD, SEC
WAVE-HEIGHT AMPLIFICATION
BASE PLAN
DRY BULK TERMINAL
0
30
60
90
120
220
320
420
0
2
4
6
8
10

PLATE 51

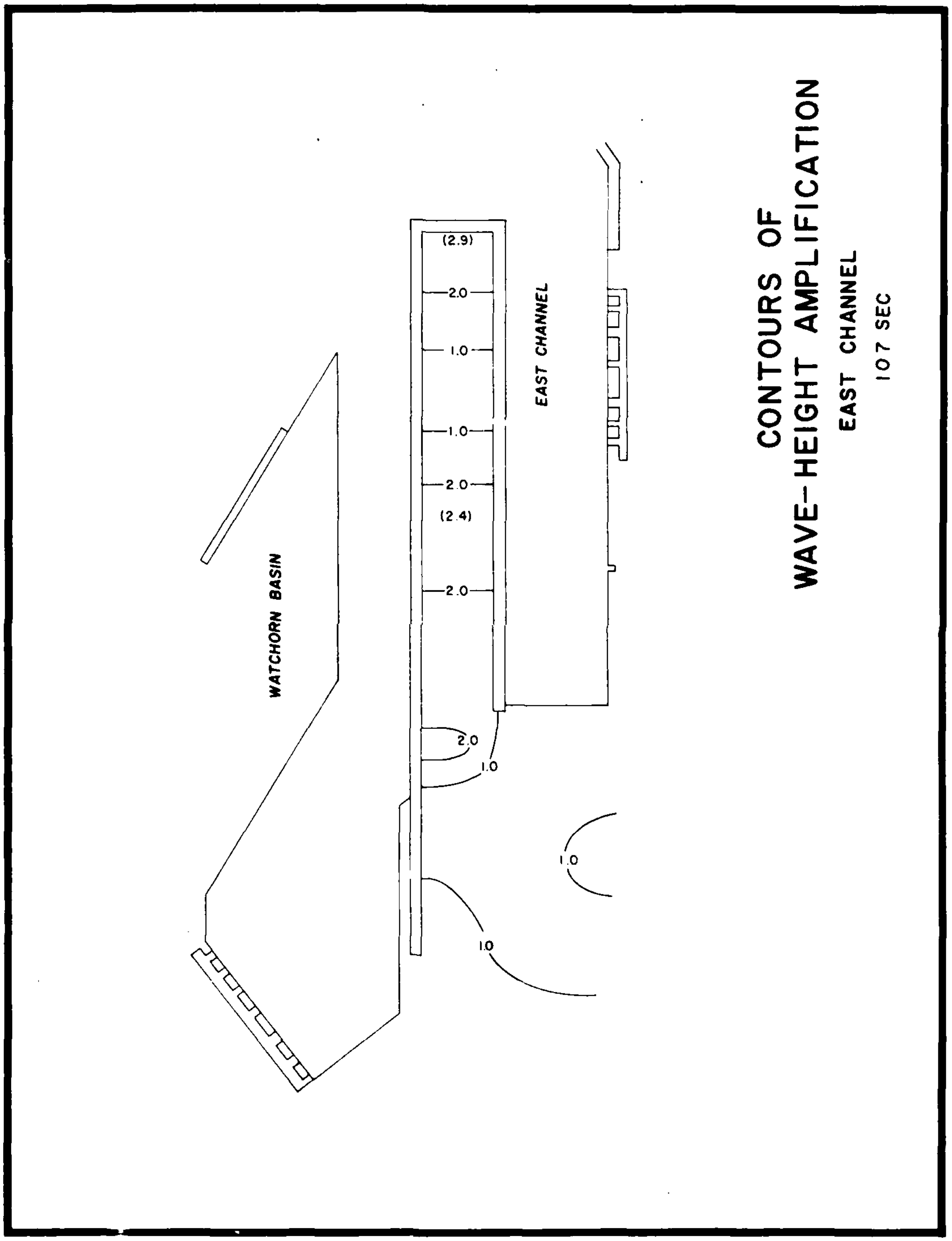
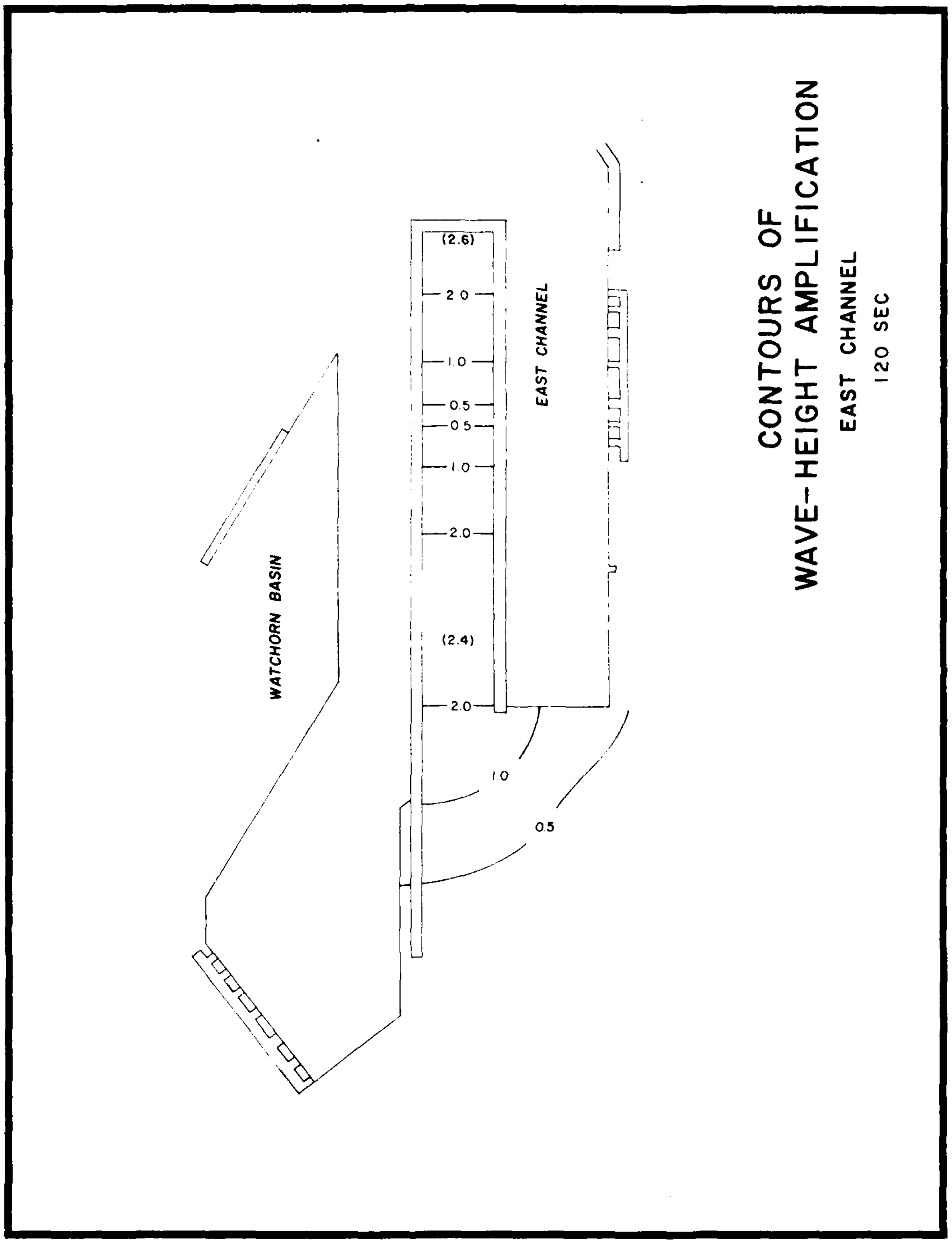

CONTOURS OF
WAVE-HEIGHT AMPLIFICATION
EAST CHANNEL
107 SEC
EAST CHANNEL
WATCHORN BASIN
(2.9)
2.0
1.0
1.0
2.0
(2.4)
2.0
2.0
1.0
1.0
1.0

PLATE 52


CONTOURS OF
WAVE-HEIGHT AMPLIFICATION
EAST CHANNEL
120 SEC
EAST CHANNEL
WATCHORN BASIN
(2.6)
2.0
1.0
0.5
0.5
1.0
2.0
(2.4)
2.0
1.0
0.5

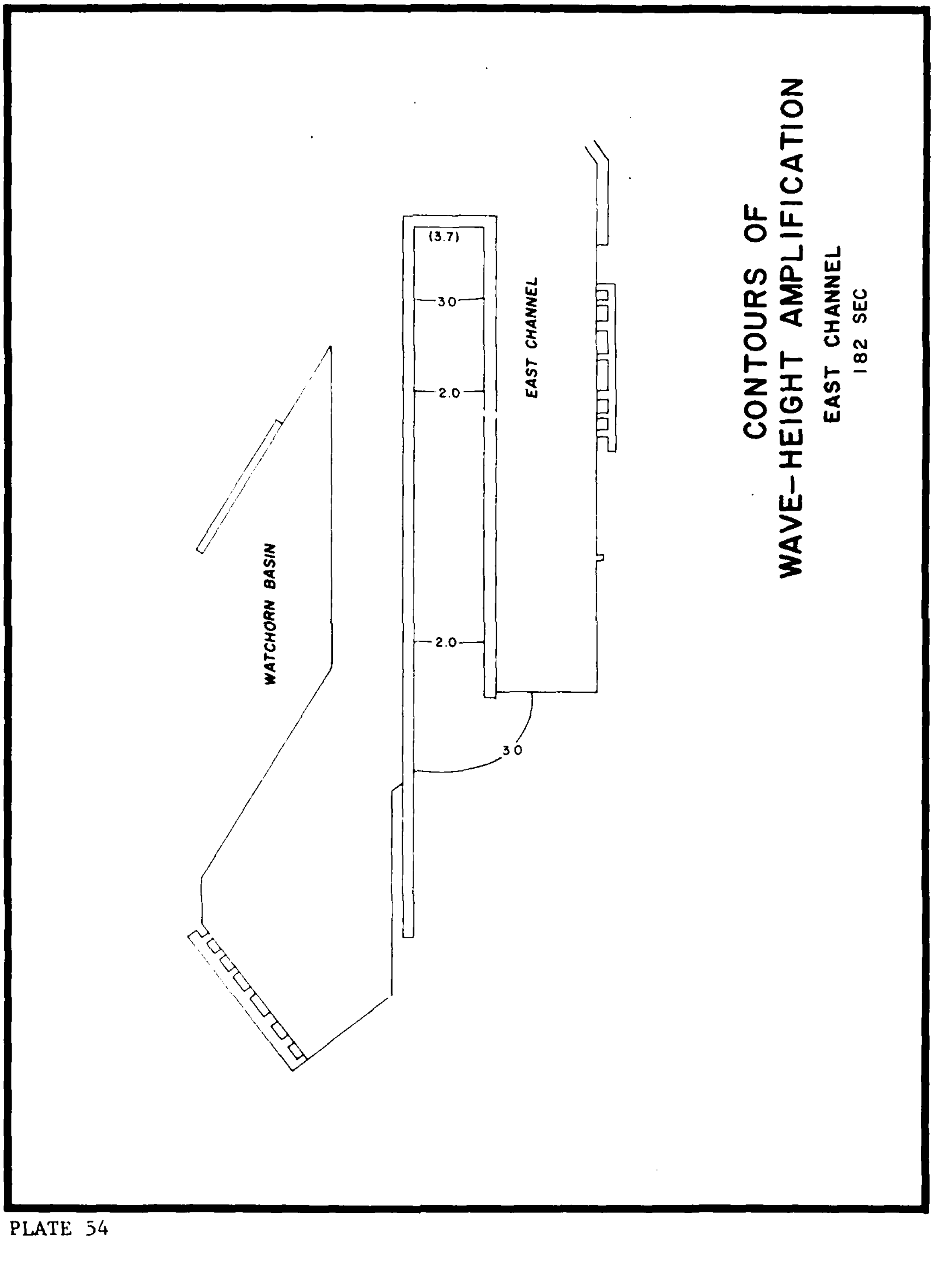
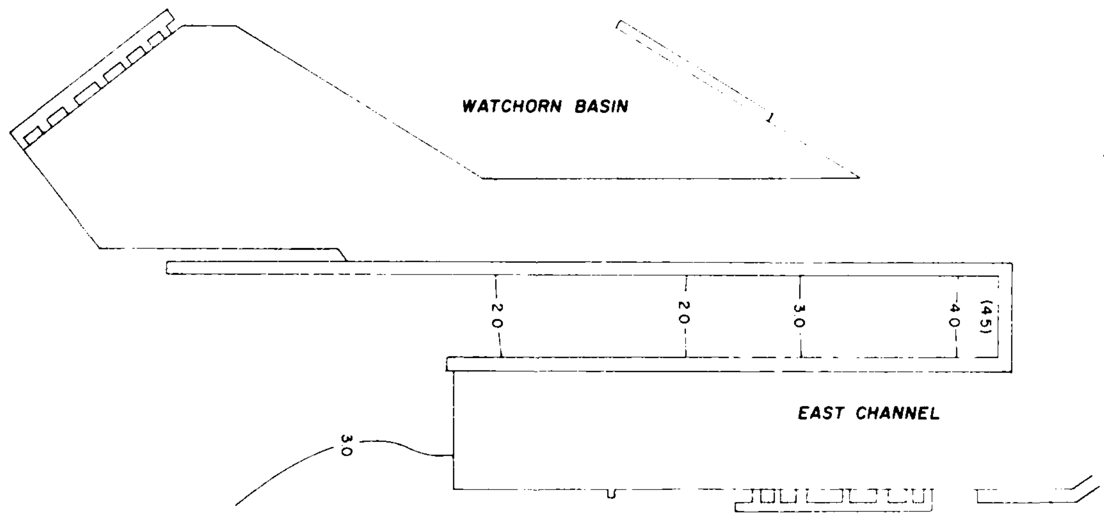
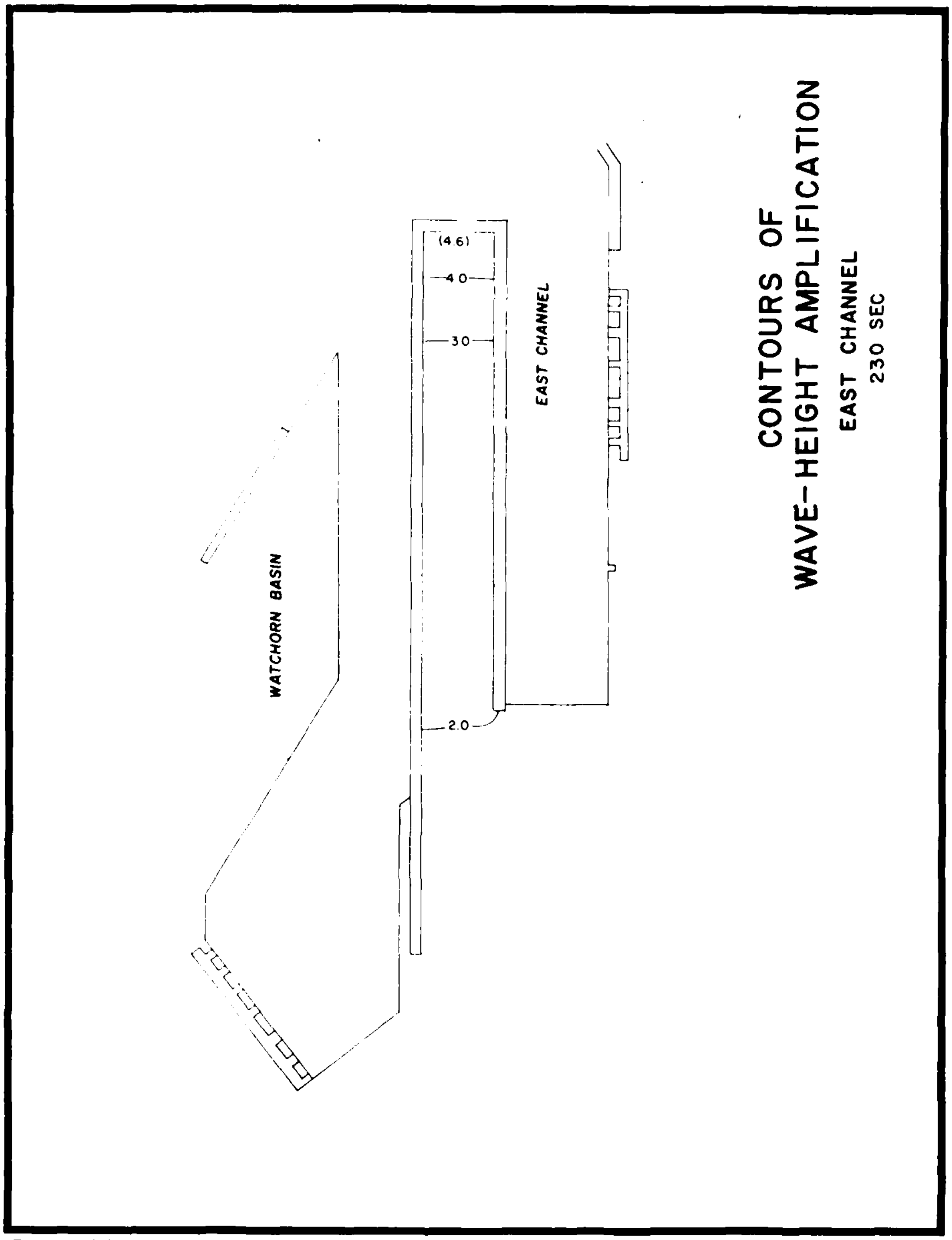
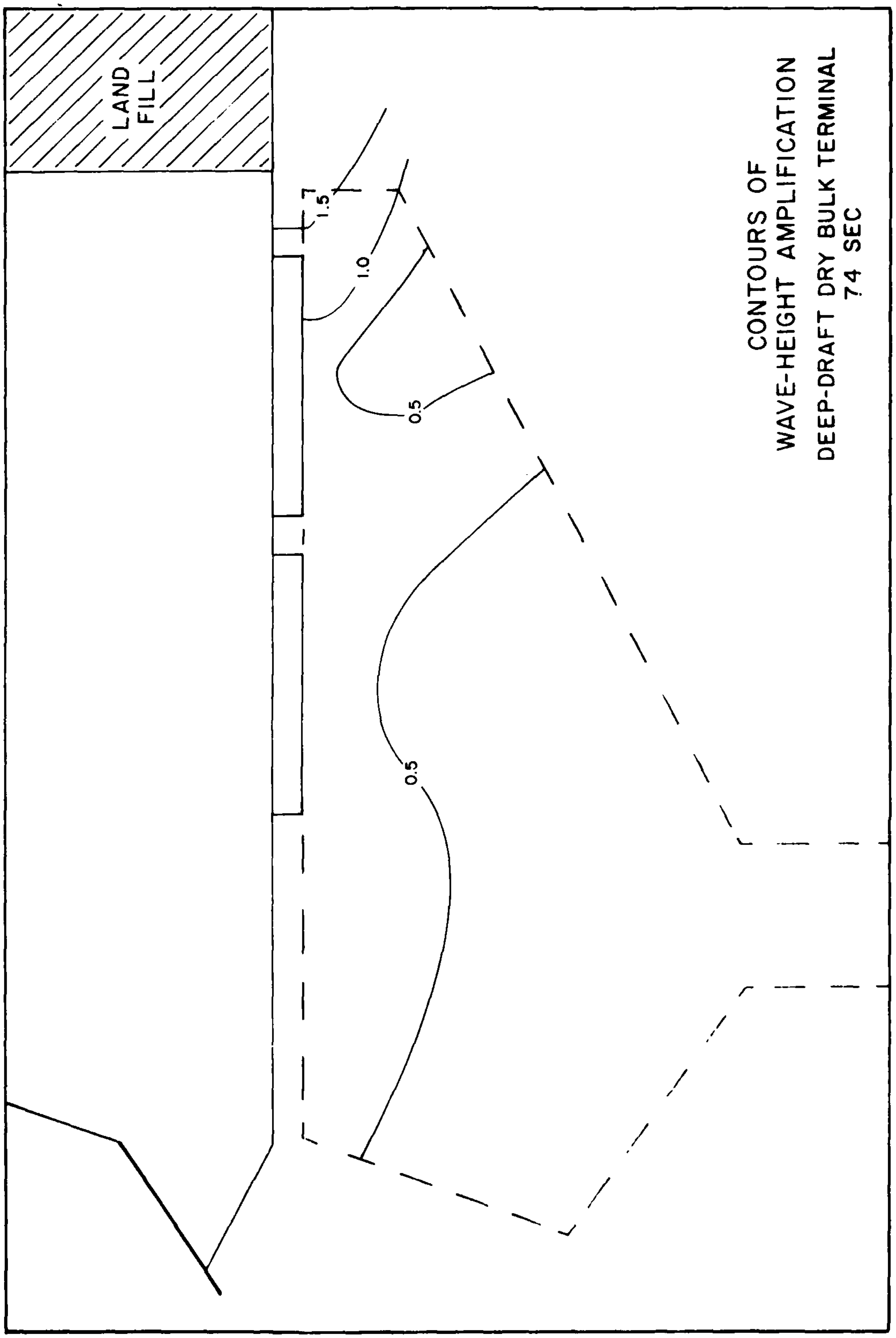

CONTOURS OF
WAVE-HEIGHT AMPLIFICATION
EAST CHANNEL
182 SEC
WATCHORN BASIN
EAST CHANNEL
(3.7)
3.0
2.0
2.0
3.0

PLATE 54



CONTOURS OF
WAVE-HEIGHT AMPLIFICATION
EAST CHANNEL
218 SEC


CONTOURS OF
WAVE-HEIGHT AMPLIFICATION
EAST CHANNEL
230 SEC
EAST CHANNEL
WATCHORN BASIN
(4.6)
4.0
3.0
2.0


CONTOURS OF
WAVE-HEIGHT AMPLIFICATION
DEEP-DRAFT DRY BULK TERMINAL
7.4 SEC
LAND
FILL
1.5
1.0
0.5
0.5

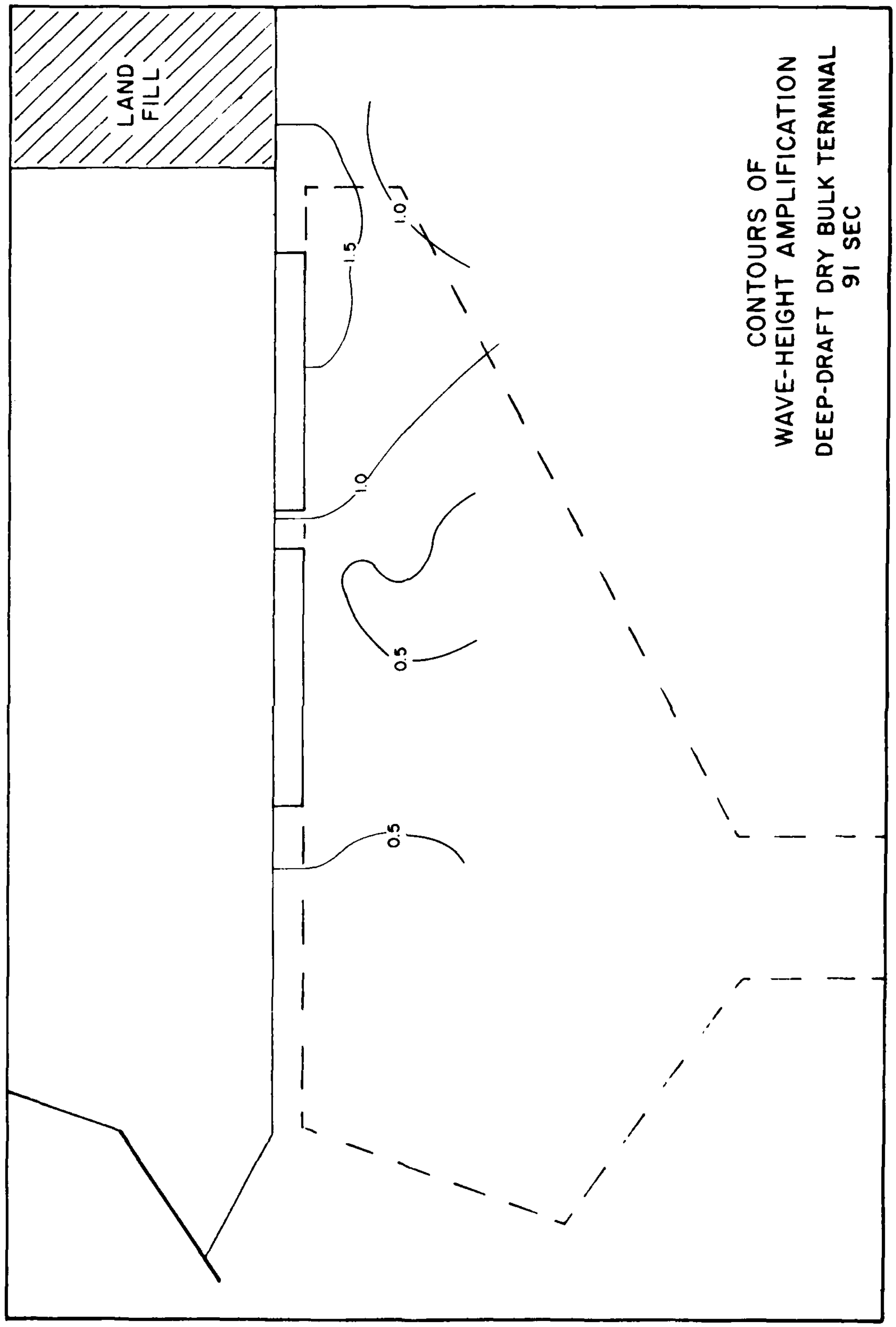
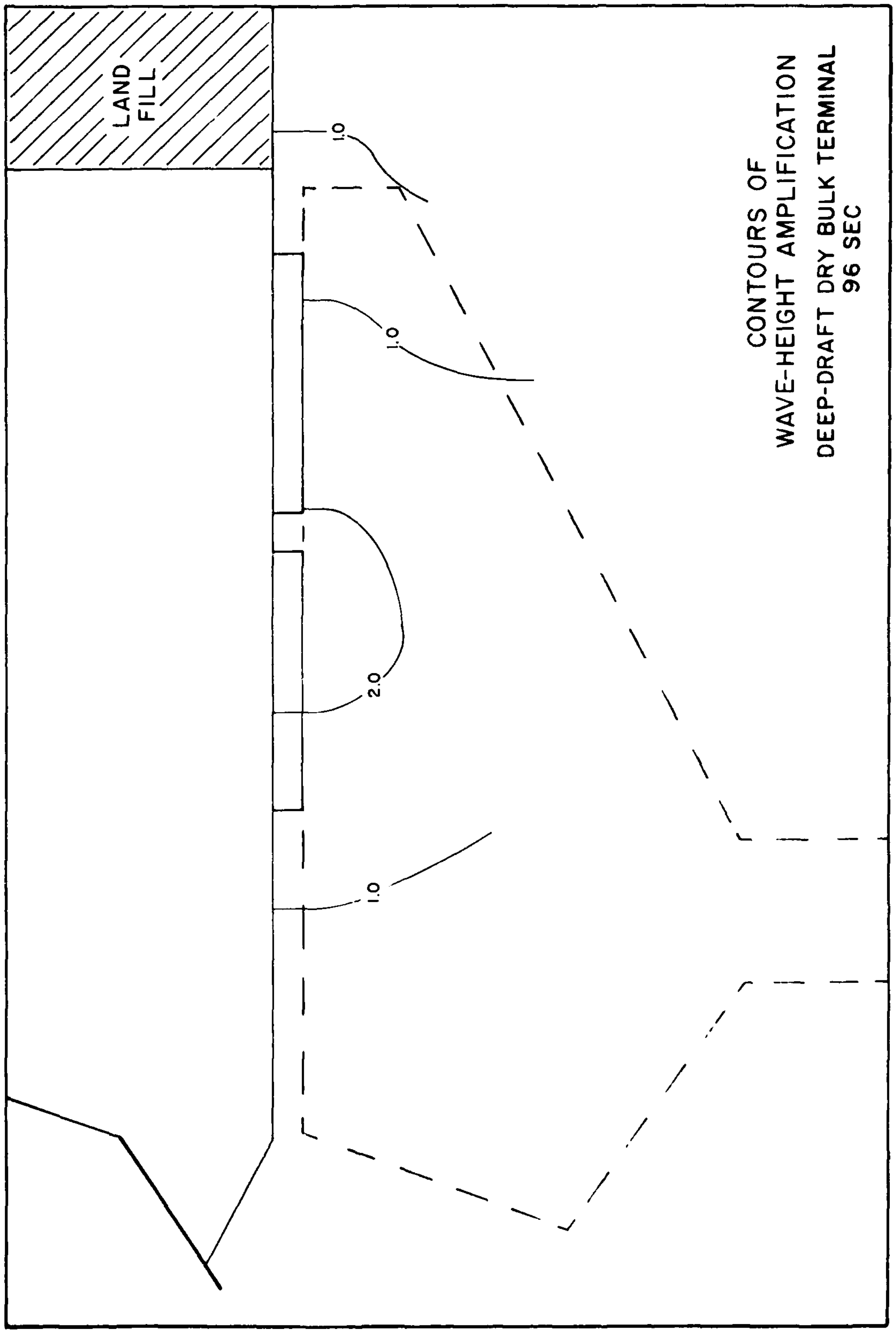

CONTOURS OF
WAVE-HEIGHT AMPLIFICATION
DEEP-DRAFT DRY BULK TERMINAL
91 SEC
LAND
FILL
1.0
1.5
1.0
0.5
0.5

PLATE 58



CONTOURS OF
WAVE-HEIGHT AMPLIFICATION
DEEP-DRAFT DRY BULK TERMINAL
96 SEC

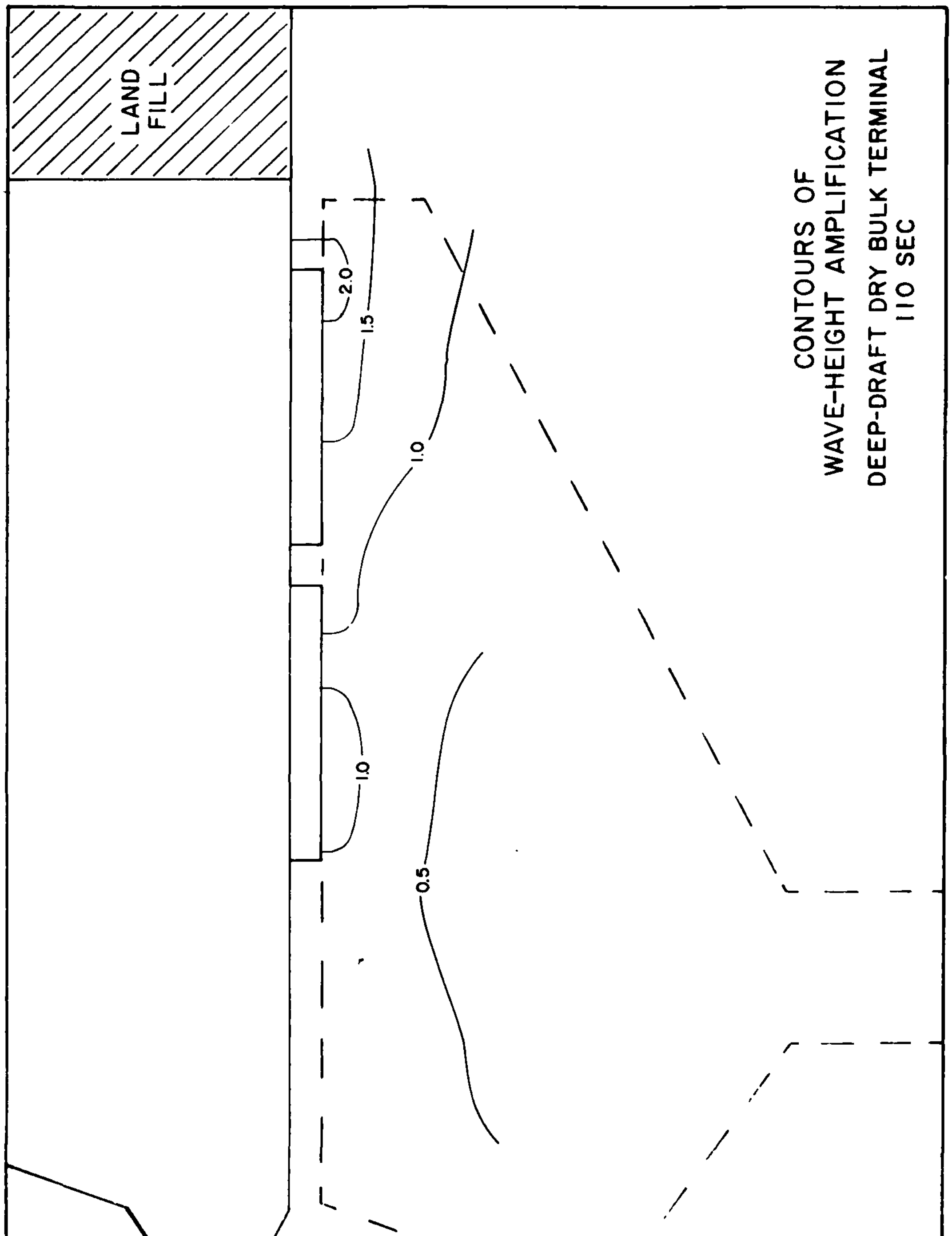
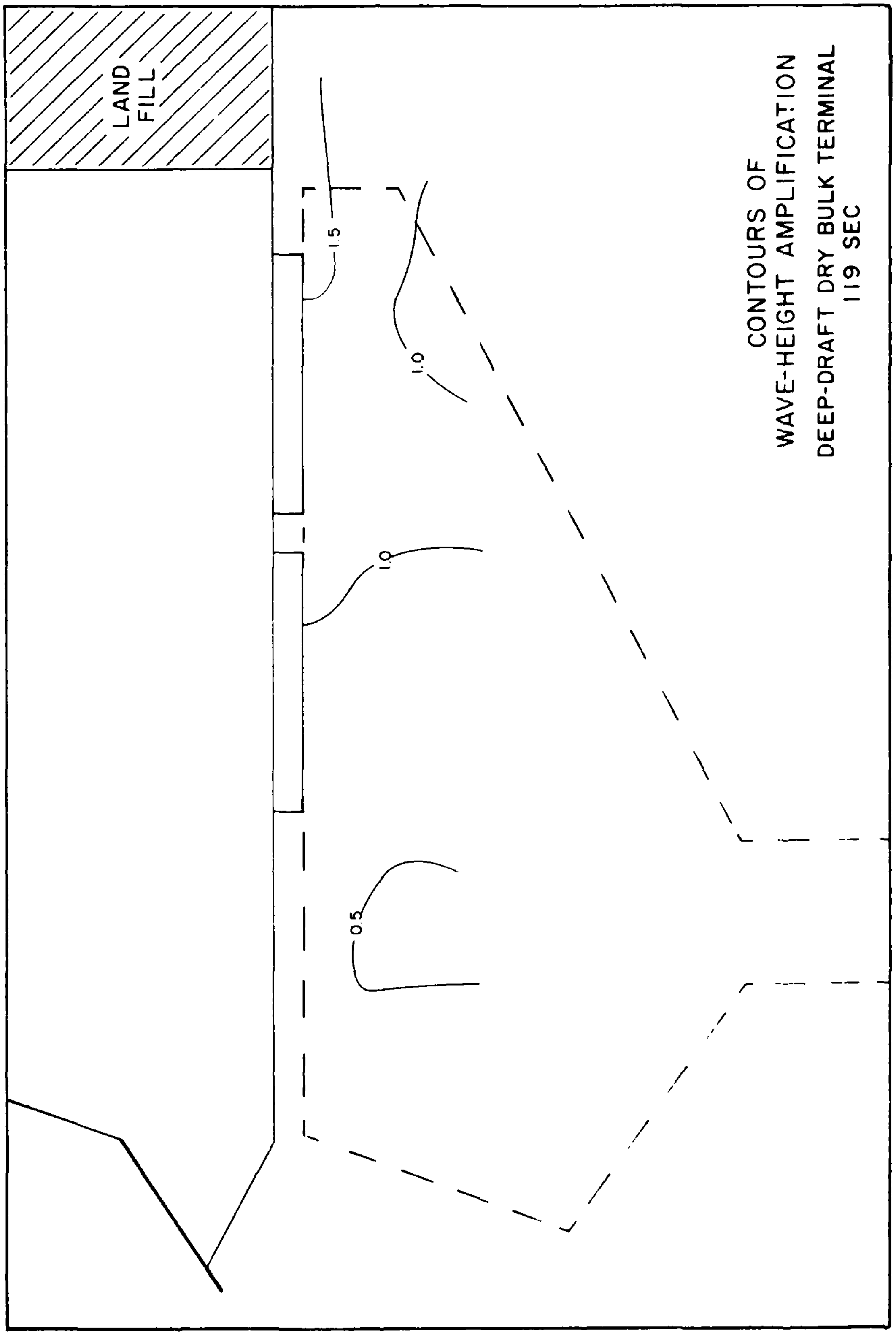

CONTOURS OF
WAVE-HEIGHT AMPLIFICATION
DEEP-DRAFT DRY BULK TERMINAL
110 SEC
LAND
FILL
2.0
1.5
1.0
1.0
0.5

PLATE 60


CONTOURS OF
WAVE-HEIGHT AMPLIFICATION
DEEP-DRAFT DRY BULK TERMINAL
119 SEC
LAND
FILL
1.5
1.0
1.0
0.5

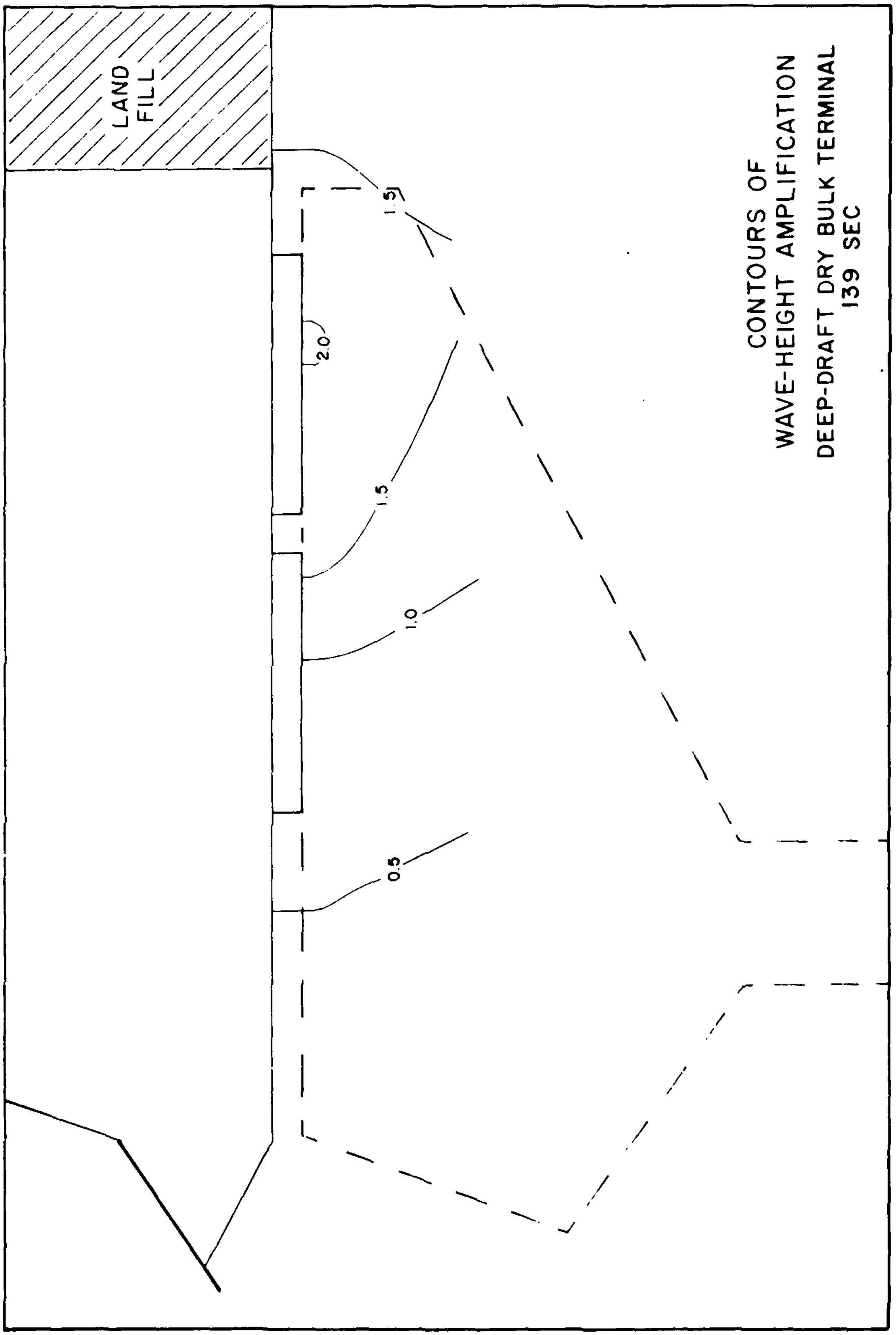
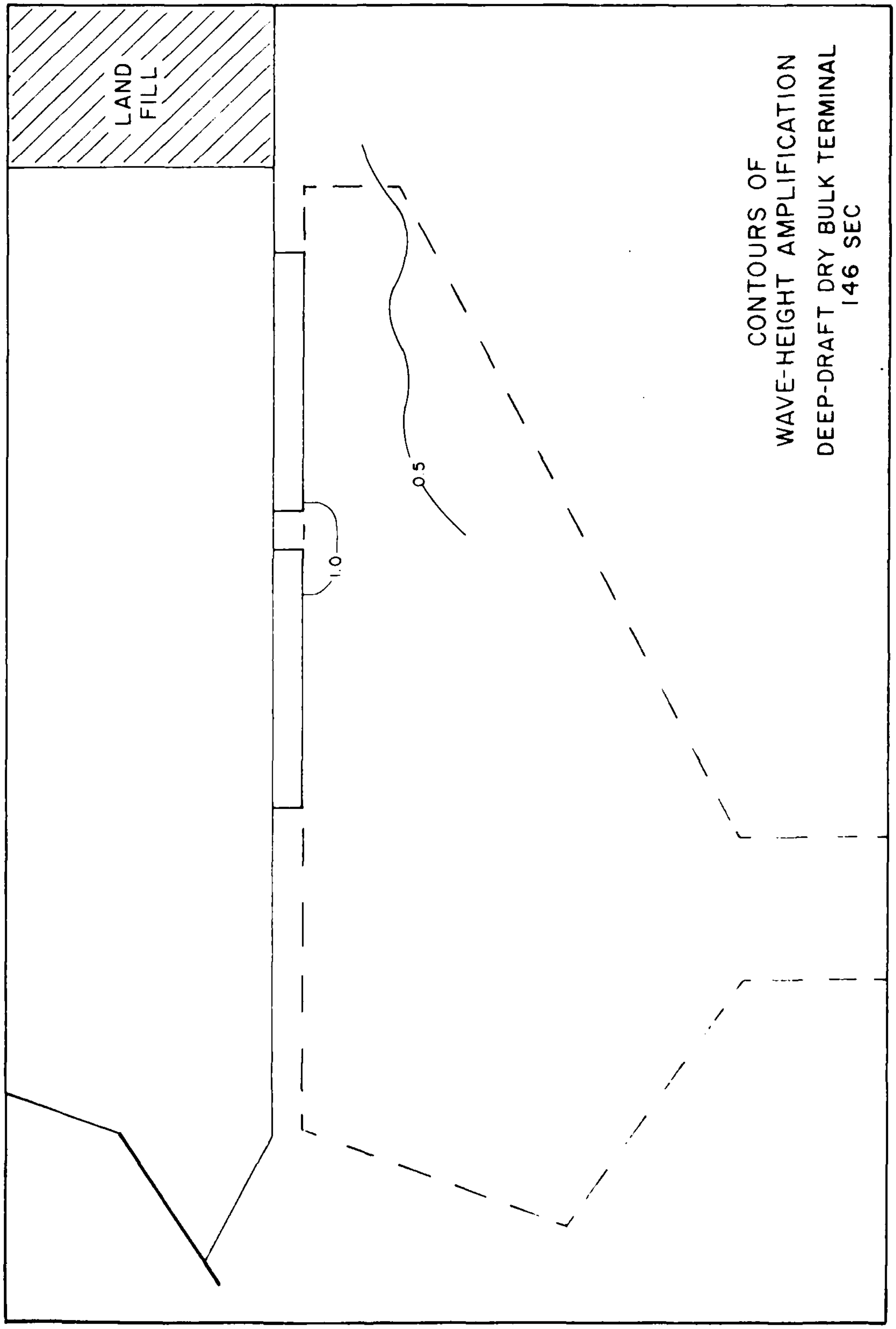
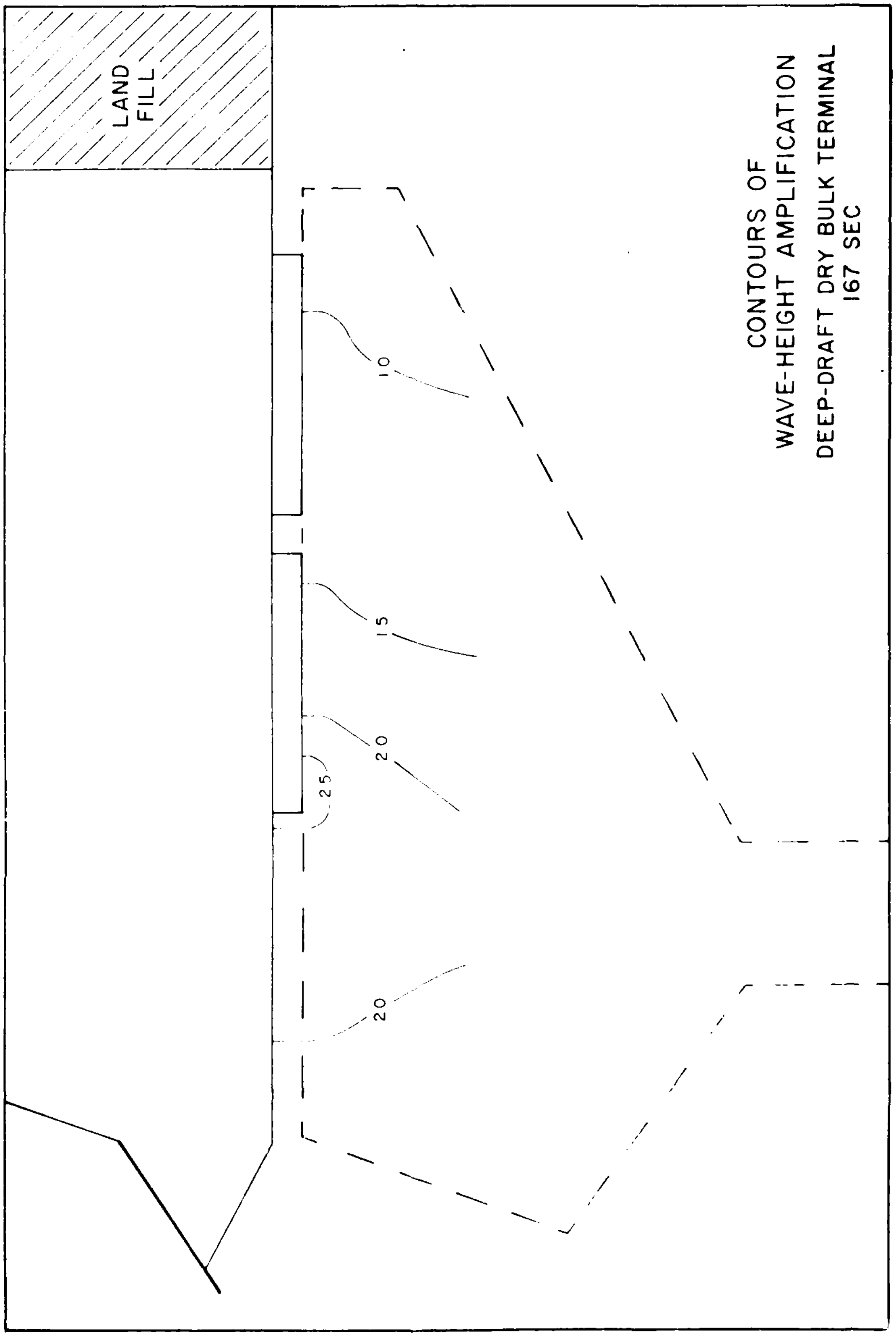

CONTOURS OF
WAVE-HEIGHT AMPLIFICATION
DEEP-DRAFT DRY BULK TERMINAL
139 SEC
LAND
FILL
1.5
2.0
1.5
1.0
0.5

PLATE 62


LAND
FILL
CONTOURS OF
WAVE-HEIGHT AMPLIFICATION
DEEP-DRAFT DRY BULK TERMINAL
146 SEC
0.5
1.0


CONTOURS OF
WAVE-HEIGHT AMPLIFICATION
DEEP-DRAFT DRY BULK TERMINAL
167 SEC
LAND
FILL
10
15
20
25
20

AD-A138 940 LOS ANGELES AND LONG BEACH HARBORS MODEL STUDY; RESONANT RESPONSE OF THE..(U) COASTAL ENGINEERING RESEARCH CENTER VICKSBURG MS R R BOTTIN ET AL. JAN 84 2/2

UNCLASSIFIED CERC-MP-84-1 F/G 13/2 NL

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DATE
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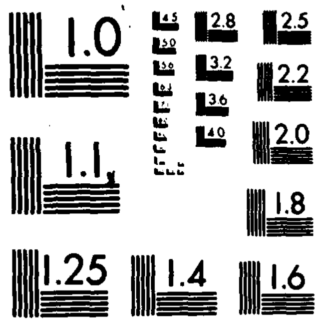
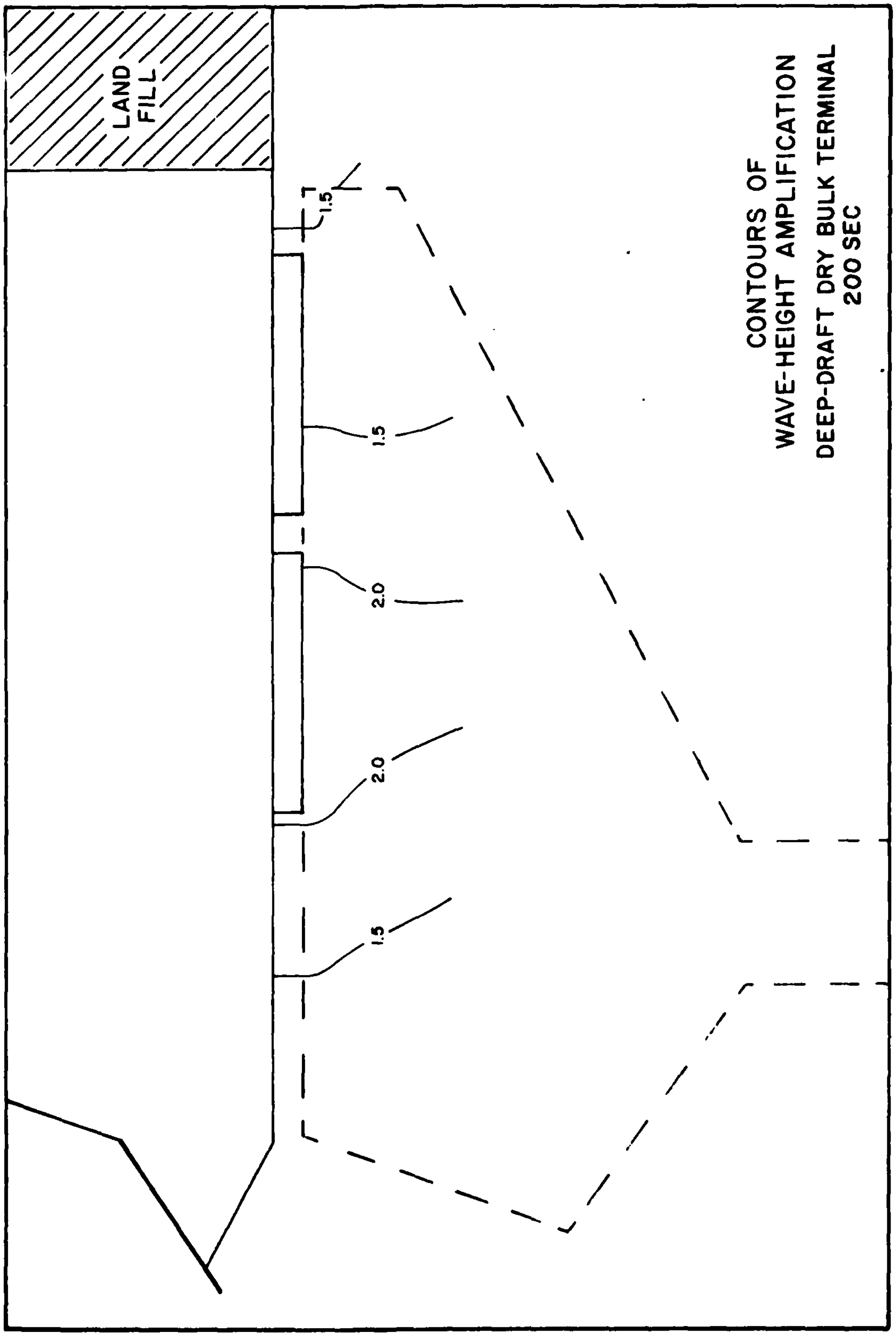


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A



CONTOURS OF
WAVE-HEIGHT AMPLIFICATION
DEEP-DRAFT DRY BULK TERMINAL
200 SEC

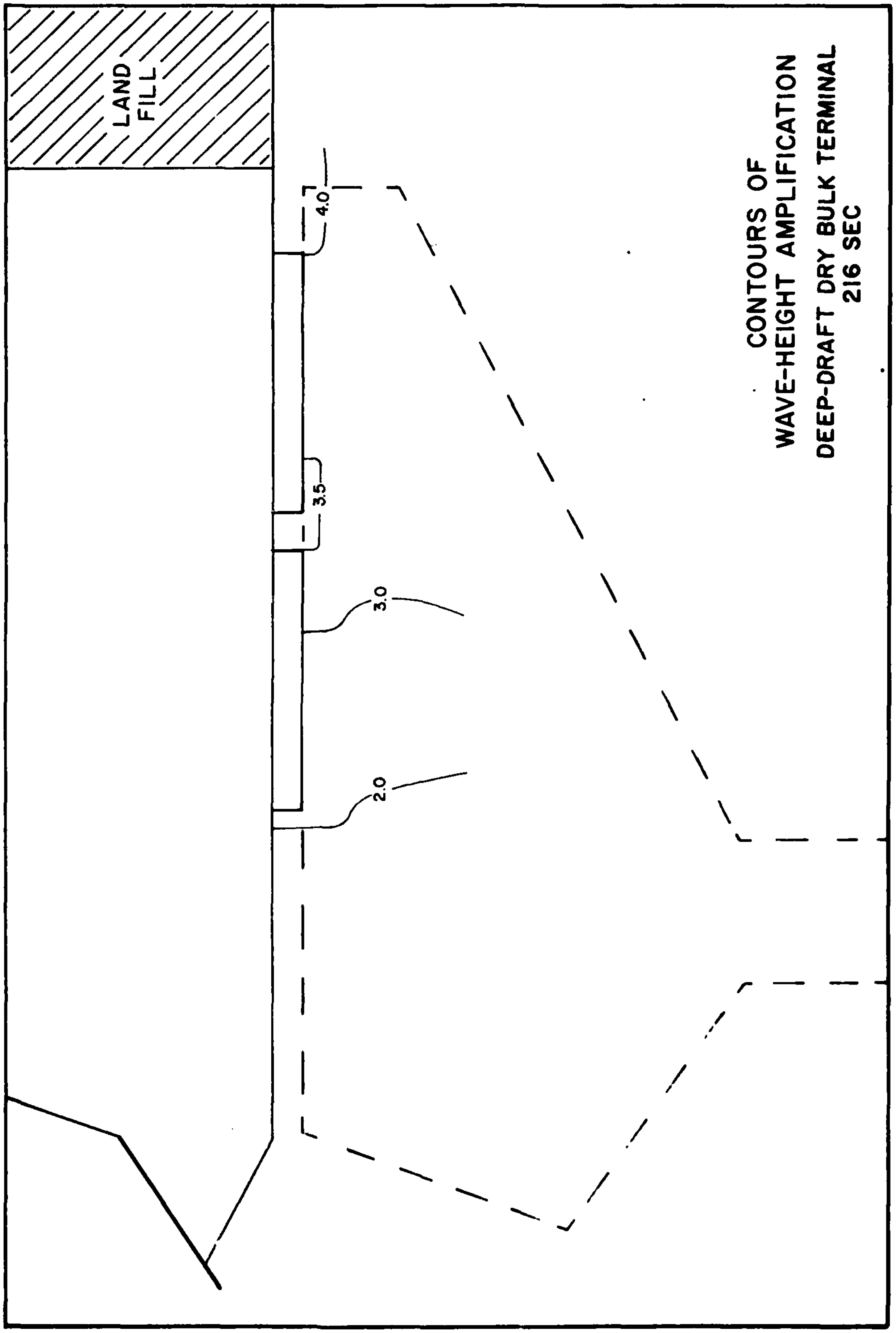

CONTOURS OF
WAVE-HEIGHT AMPLIFICATION
DEEP-DRAFT DRY BULK TERMINAL
216 SEC
LAND
FILL
4.0
3.5
3.0
2.0

PLATE 66

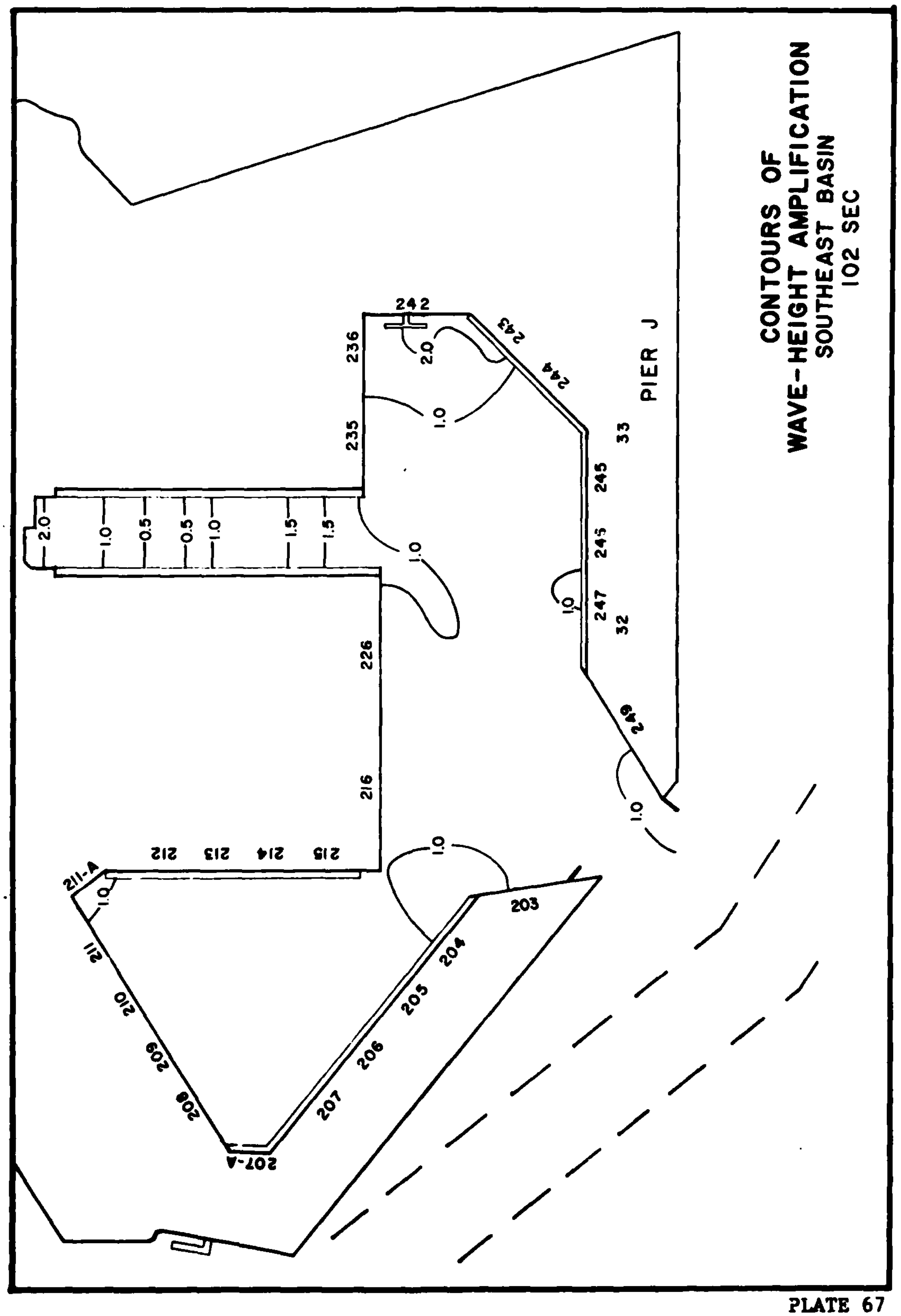
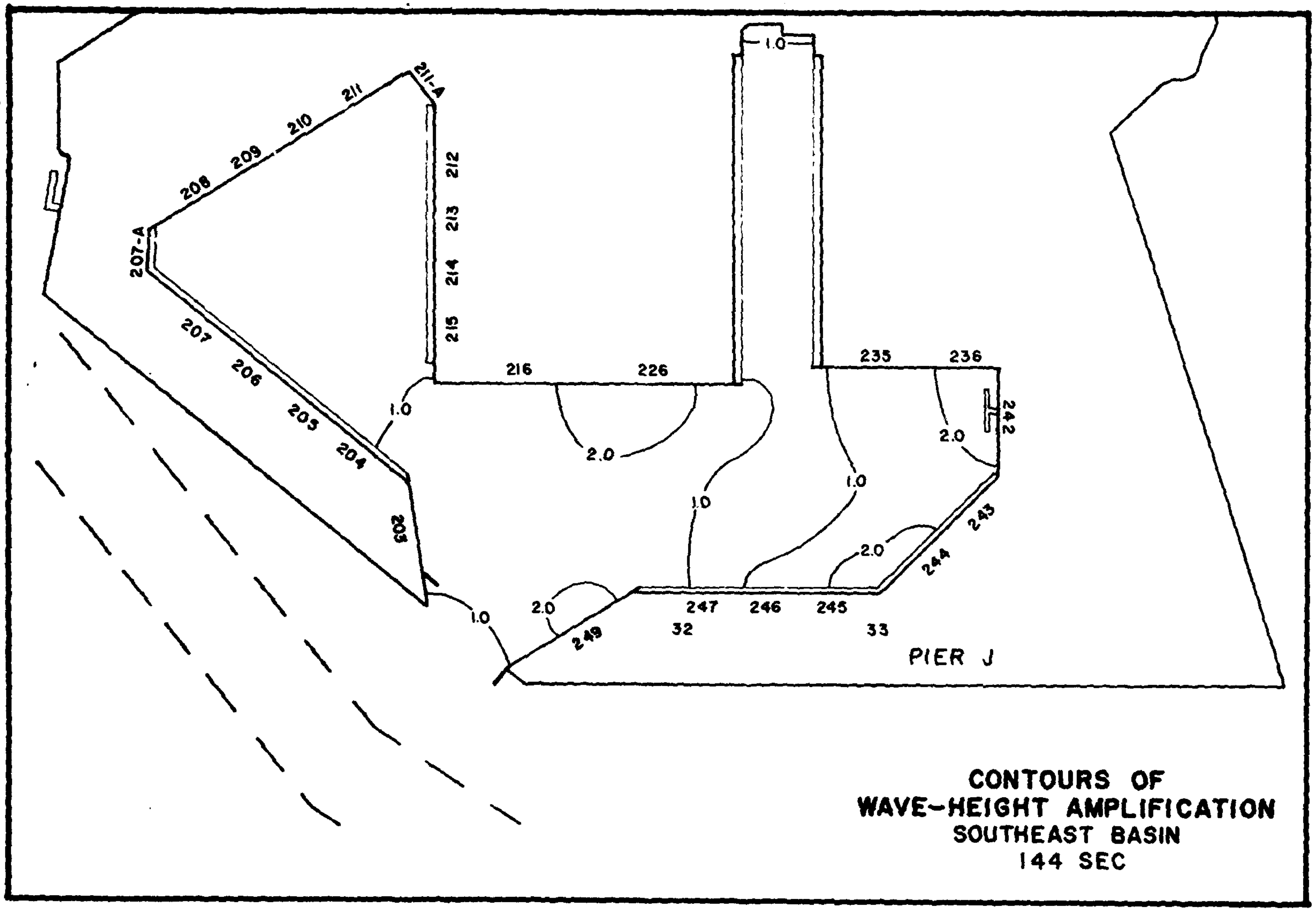
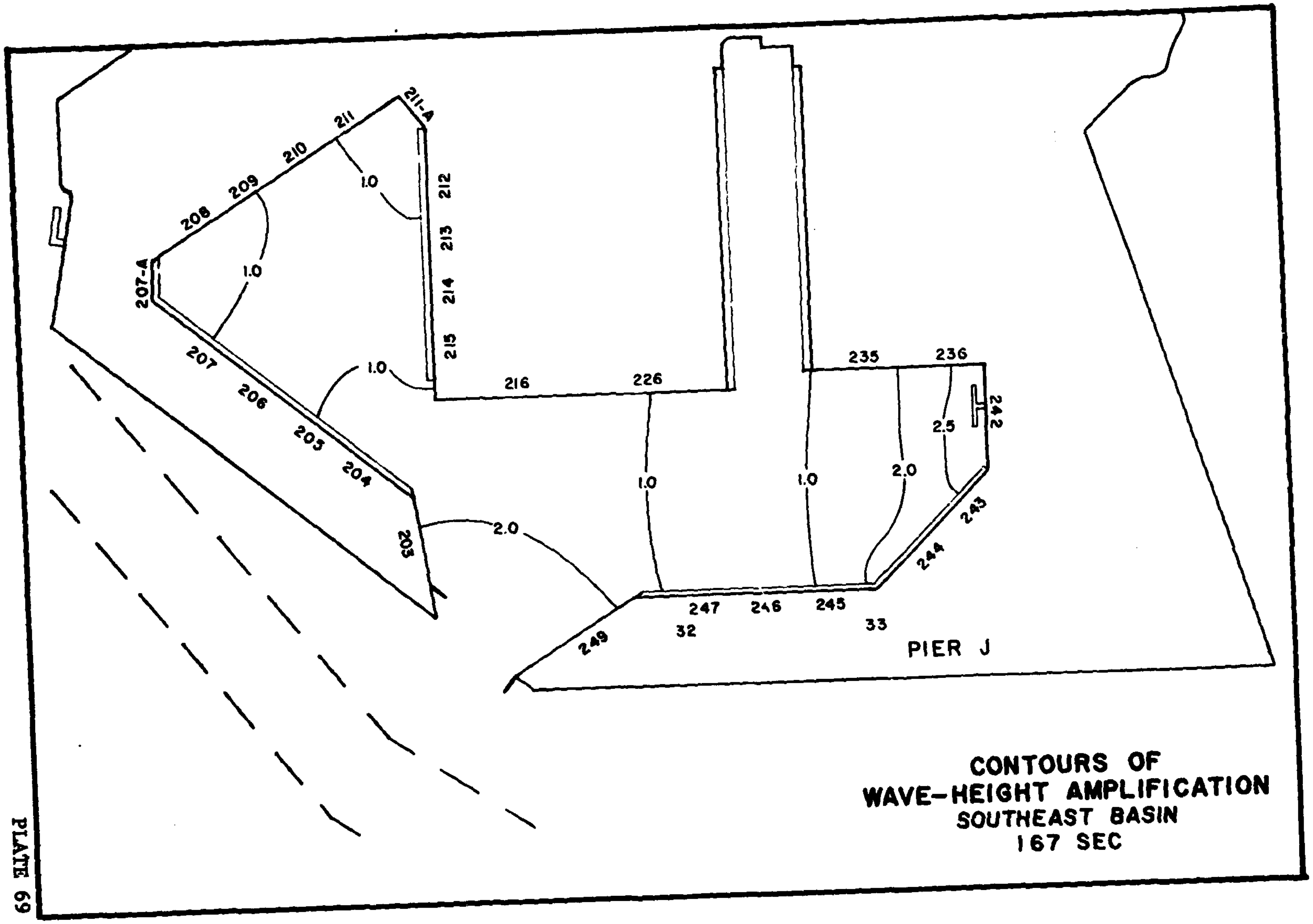

CONTOURS OF
WAVE-HEIGHT AMPLIFICATION
SOUTHEAST BASIN
102 SEC
PIER J
242
243
244
236
235
33
245
245
247
32
249
226
216
2.0
1.0
0.5
0.5
1.0
1.5
1.5
211-A
212
213
214
215
211
210
209
208
207-A
207
206
205
204
203

PLATE 67

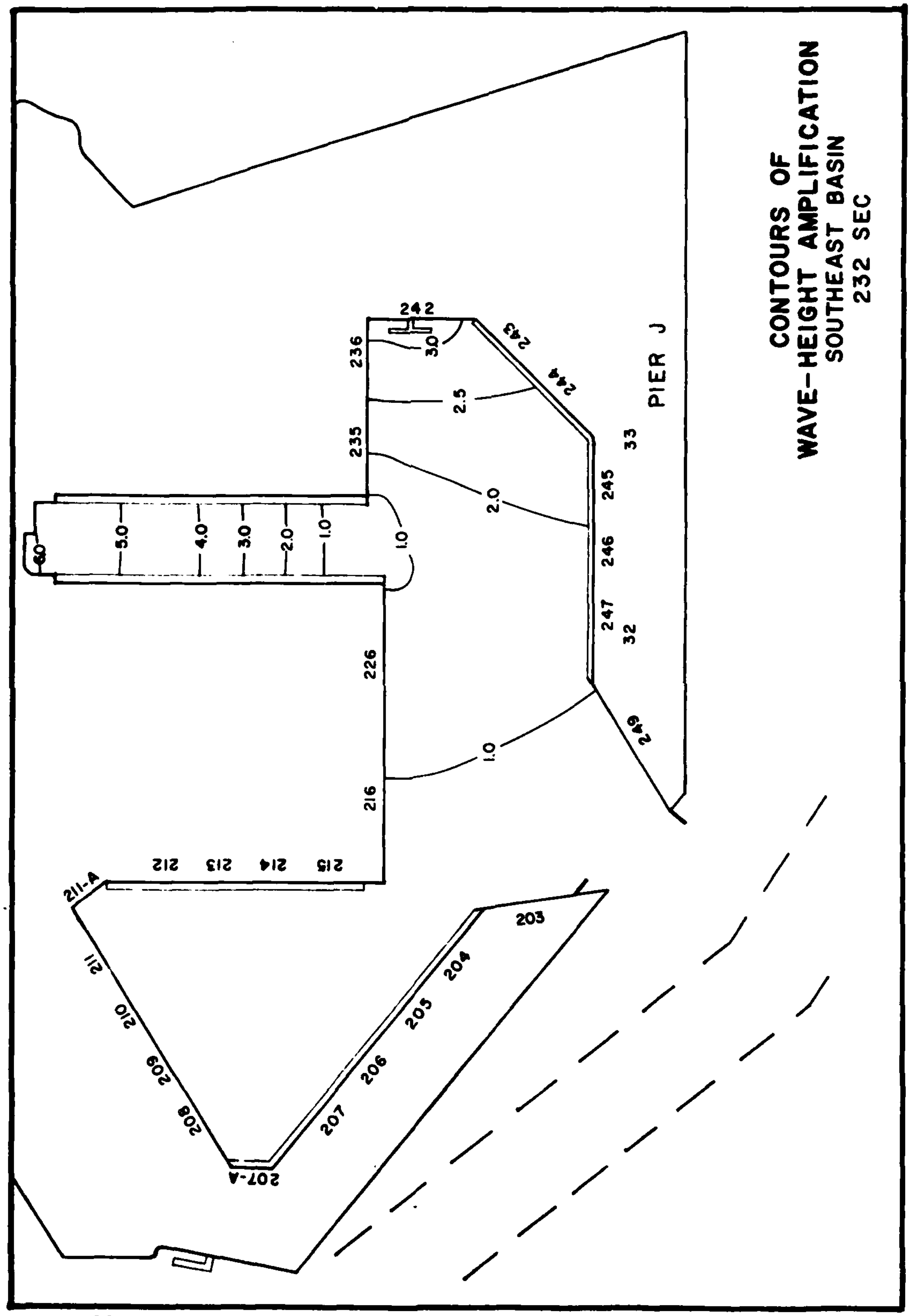


CONTOURS OF
WAVE-HEIGHT AMPLIFICATION
SOUTHEAST BASIN
144 SEC

PLATE 68

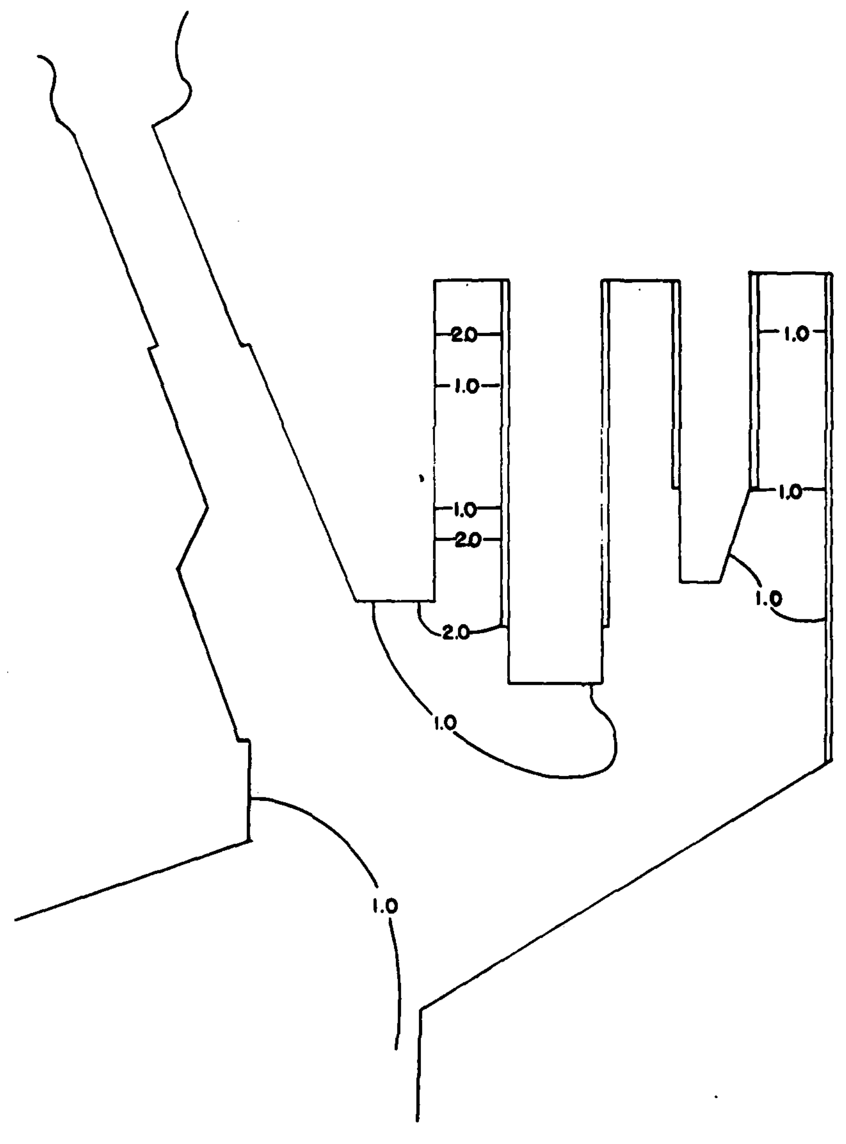


CONTOURS OF
WAVE-HEIGHT AMPLIFICATION
SOUTHEAST BASIN
167 SEC

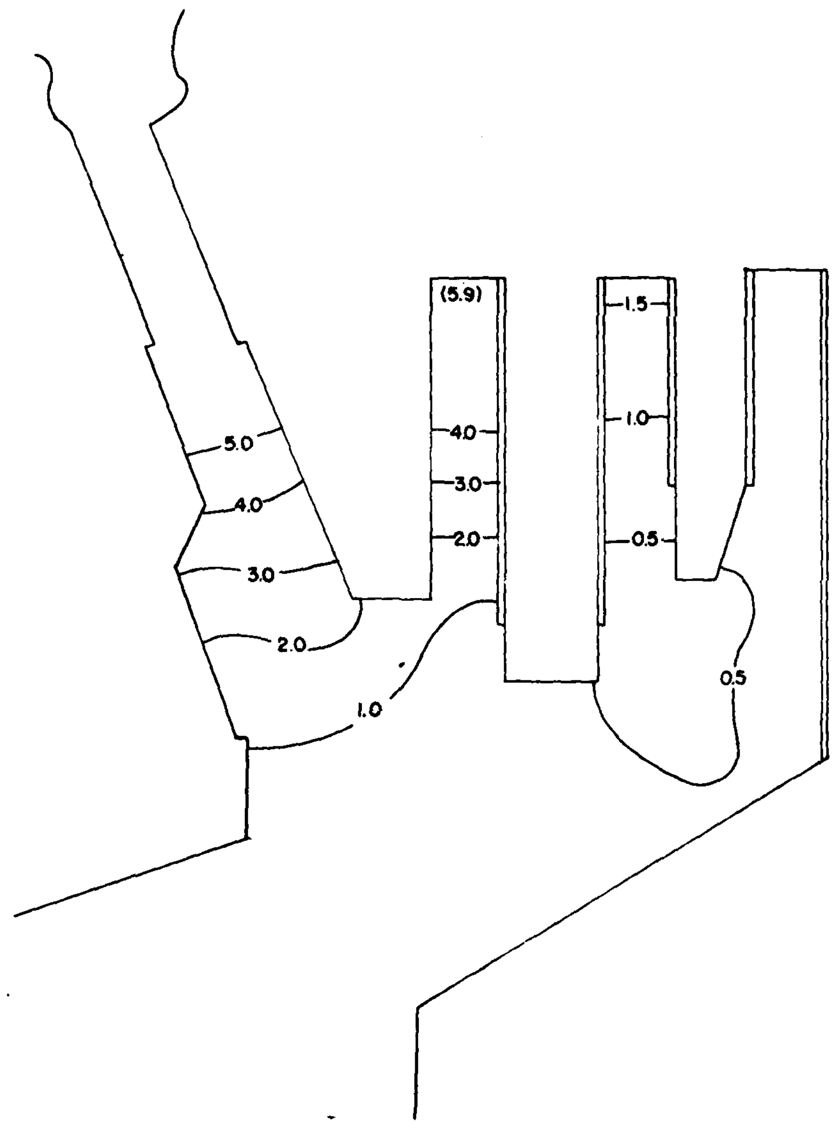


CONTOURS OF
WAVE-HEIGHT AMPLIFICATION
SOUTHEAST BASIN
232 SEC
PIER J

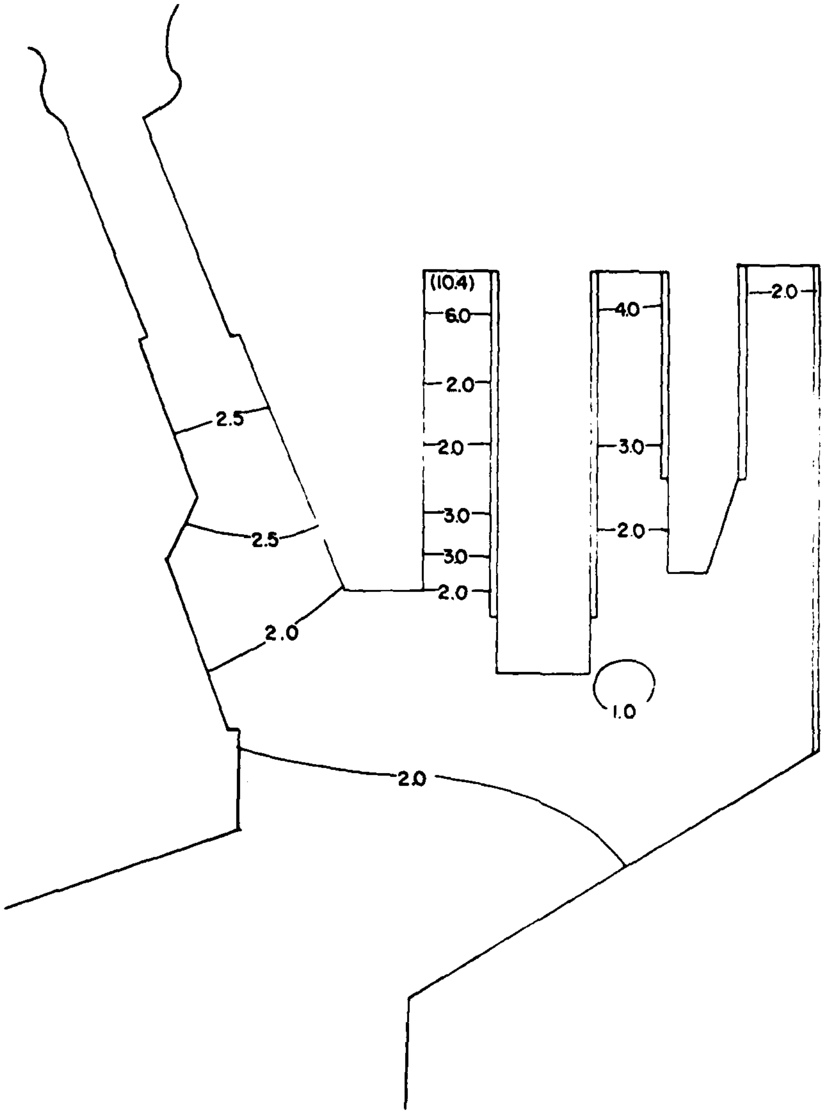
PLATE 70



CONTOURS OF
WAVE-HEIGHT AMPLIFICATION
EAST BASIN AND BACK CHANNEL
91 SEC



CONTOURS OF
WAVE-HEIGHT AMPLIFICATION
EAST BASIN AND BACK CHANNEL
208 SEC



CONTOURS OF
WAVE-HEIGHT AMPLIFICATION
EAST BASIN AND BACK CHANNEL
222 SEC

APPENDIX A: NOTATION

h_m	Model depth of the inner harbor
H_i	Incident wave height
H_m	Model wave height
H_r	Vertical scale ratio
H_s	Significant wave height
H_w^M	Model-generated wave height
H_w^P	Prototype-generated wave height
K_r	Refraction coefficient
$K_s^{M,G}$	Model shoaling coefficient at the gage locations
$K_s^{M,W}$	Model shoaling coefficient at the wave generator
$K_s^{P,A}$	Prototype shoaling coefficient at the initial refracted wave front
$K_s^{P,G}$	Prototype shoaling coefficient
$K_s^{P,W}$	Prototype shoaling coefficient at wave generator
ℓ_{hm}	Horizontal length scale in the model
ℓ_{hp}	Horizontal length scale in the prototype
L_m	Model wavelength
R	Wave-height amplification factor
T_m	Model wave period
T_p	Prototype wave period
Ω	Distortion